

NASA CONFERENCE PUBLICATION

NASA **CP-2105**

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SUMMARY OF THE NASA/MSFC FY-79 SEVERE STORMS AND  
LOCAL WEATHER RESEARCH REVIEW

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September **1979**

Prepared by

NASA - George C. Marshall Space Flight Center  
Marshall Space Flight Center, Alabama 35812

# **NASA CP-2105**

## **SUMMARY OF THE NASA/MSFC FY-79 SEVERE STORMS AND LOCAL WEATHER RESEARCH REVIEW**

**September 12-13, 1979**

**Hilton Inn - Huntsville, Alabama**

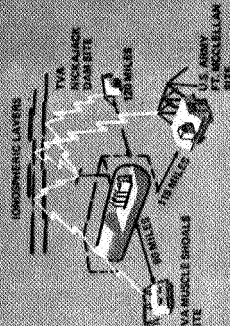
**NASA/MSFC  
Atmospheric Sciences Division  
(ES81)  
Marshall Space Flight Center, AL 35812**

# SEVERE STORMS AND LOCAL WEATHER RESEARCH



CLOUD PHYSICS

DOPPLER LIDAR



STORM IONOSPHERIC COUPLING

MESO/STORM SCALE RESEARCH AND FIELD EXPERIMENTS



LIGHTNING CAMERA AND SENSORS



UPGRADE ACPL



NEW SENSOR SYSTEM REQUIREMENTS

## SUPPORTING RESEARCH AND TECHNOLOGY

CLIMATE RESEARCH

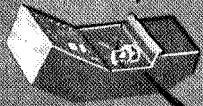


CLOUD COVER DATA SETS AND MODELS



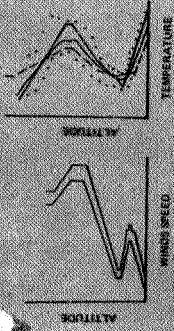
GLOBAL WEATHER RESEARCH

### MSFC ATMOSPHERIC PROCESSES PROGRAM (OSTA)



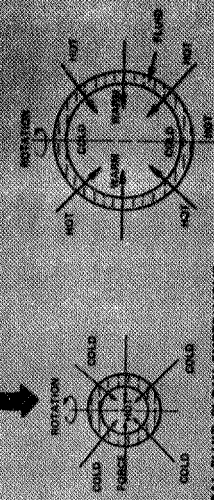
ATMOSPHERIC GENERAL CIRCULATION EXPERIMENT/SPACELAB

REFERENCE ATMOSPHERES AND MODELS



MISSION OPERATIONS PLANNING

## FLIGHT PROJECTS



GEOPHYSICAL FLUID FLOW EXPERIMENT

ATMOSPHERIC GENERAL CIRCULATION EXPERIMENT/SPACELAB

## FOREWORD

Three general areas of NASA's Severe Storms and Local Weather Research Program included in this review were Cloud Physics, Atmospheric Electricity, and Storm/Mesoscale Dynamics research. The final titles of the individual presentations varied somewhat, depending on the particular emphasis of the designated presenters. The technical aspects of the research efforts were stressed. The individual presentations were developed to insure visibility to the major accomplishments, significant current efforts and specific plans/recommendations for the coming year's research.

There were many research topics to cover and it was very important that each person discipline his presentation time. We endeavored to make the review just that--a review of the major aspects of the sponsored research endeavors relative to the NASA Program goals. We planned for the review to be informal, insofar as practical, and a research team spirit did prevail and was further enhanced by discussions. To provide for a follow-up by the various participants and attendees each investigator was requested to prepare a brief outline of his research project. These are assembled in this report and will be distributed to all attendees and interested individuals.

We recognized that there would be a rather wide range of scopes relative to the individual research efforts. Some are very modest or have been under way for only a short period of time, whereas others are larger or have had nearly a year of activity. However, the opportunity to learn what each investigator is doing and develop the team relationship necessary for a meaningful research program were considered most important though these variations existed. In this context, on the following page, I would like to restate the goal of the NASA Severe Storms and Local Weather Research Program. It is toward this goal that all research sponsored by the program should be directed.

### PROGRAM GOAL

**To** conduct applied research and development using space related techniques and observations that will increase the basic understanding of **storms** and local weather and that will help to improve the accuracy and timeliness **of** local weather forecasts and severe weather warnings.

The contributions and cooperation **of** all participants and attendees are appreciated. This enabled the review of proceed smoothly and timely.

William W. Vaughan, Chief  
Atmospheric Sciences Division  
NASA/Marshall Space Flight Center

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## NASA/MSFC **FY-79** SEVERE STORMS AND LOCAL WEATHER RESEARCH **REVIEW**

### Introduction:

Each year NASA supports research efforts in various disciplinary program areas. The coordination and exchange of information among those sponsored by NASA to conduct research studies are important elements of a program. In 1978, the NASA Office of Space and Terrestrial Applications via an Applications Notice (AN) invited interested investigators throughout the country to communicate their research ideas in the research topics identified in the AN. Those proposals in the Severe Storms and Local Weather Research area selected and assigned to the NASA-Marshall Space Flight Center's Atmospheric Sciences Division for technical monitorship, together with the research efforts included in the FY-79 MSFC Research and Technology Operating Plan (RTOP), were the source of principal focus and participants for this review. While time did not permit all research topics to be covered, the majority were accommodated during the two-day review.

The unedited outlines provided by the investigators on their research efforts are presented in this report.

As noted, the principal purpose of the review was to provide those having major research activities sponsored by the NASA's Severe Storms and Local Weather Research Program, and assigned to NASA-Marshall Space Flight Center's Atmospheric Sciences Division, an opportunity to meet and discuss their programs and future plans. In addition, the review provided the NASA Severe Storms and Local Weather Research Program Manager, Dr. James Dodge, the NASA Atmospheric Processes Branch Chief, Dr. Shelby Tilford, and the NASA/MSFC Research Program Manager, Dr. William W. Vaughan, with a current status report plus research plans for use in identifying future program needs.

## AGENDA

NASA/MSFC FY-79 Severe Storms and Local Weather Research Review

September 12-13, 1979

Hilton Inn, Huntsville, Alabama

Wednesday, September 12, 1979

**I. REVIEW OVERVIEW VIEWS (8:30 - 8:45 A.M.)**

Remarks

W. Vaughan/J. Dodge

**II. CLOUD PHYSICS RESEARCH (8:45 - 11:30 A. M.)**

Introductory Remarks

W. Vaughan

Science Review

R. Smith

CPL Status-Gravimetric Verification of  
Saturator Performance

J. Anderson

Ice Multiplication & Data Acquisition System

J. Carter

Stable Electrostatic Levitation of a Thin,  
Charged-Droplet Layer in a One-G

Static Diffusion Chamber

D. Bowdle

Ice Crystal Growth - KC-135 Experiment

V. Keller/O. Vaughan

Cloud Physics-Atmospheric Electricity Links

A. Few

**III. LUNCH (11:30 A.M. - 1:00 P.M.)**

**IV. ATMOSPHERIC ELECTRICITY RESEARCH (1:00 - 5:30 P. M.)**

Introductory Remarks

W. Vaughan

Severe Storm Electricity-Tornado Activity

D. Rust/W. Taylor/R. Arnold

Storm Severity Detection (RF)

R. Johnson

Remote Observation of Severe Storms

R. Orville

Low Light Level TV Observations

S. Clifton/K. Hill

NOSL & U-2 Measurements

B. Vonnegut/O. Vaughan

U-2 Measurements & TRIP Experiences

M. Brook

Florida Storm Electrical Observations

P. Krider

Severe Storm Measurements (RF)

D. LeVine

Aircraft Measurements

R. Markson

**V. DINNER (6:00 P. M.)**

NASA/MSFC FY-79 Severe Storms and Local Weather Research Review

September 12-13, 1979

Hilton Inn, Huntsville, Alabama

Thursday, September 13, 1979

VI. ATMOSPHERIC ELECTRICITY RESEARCH (cont'd) (8:30 -10:00 A. M)

Atmospheric Electricity Models	L. Parker
Lightning Sensor (RF) Efforts	T. Shumpert
Lightning Mapper Feasibility Study Status	W. Wagnon
a) Science & Application Team Plans	A. Few
b) R F Team Plans	J. Herman
c) Optical Team Plans	W. Wolf

VII. MESOSCALE/STORM DYNAMICS RESEARCH (10:00 -11:30 A. M. )

Introductory Remarks	W. Vaughan
Ionospheric-Severe Storm Coupling	R. Smith
Ionospheric Remote Sites & Operations	G. West
Acoustic & Gravity Waves Generation	N. Balachandra
Ionospheric Perturbations-Gravity Waves (1977 Case Study)	R. Hung
Airborne Doppler Lidar -Severe Storms System	J. Bilbro

VIII. LUNCH (11:30 A.M. - 1:00 P.M.)

IX. MESOSCALE/STORM DYNAMICS RESEARCH (cont'd) (1:00 - 4:30 P. M. )

AVE SESAME '79 and Cyclone Workshop	
Overview	<u>R. Turner</u> /K. Hill
Diagnostic Analysis of Severe Storms	J. Scoggins
Mesoscale Structure & Dynamics	
Relative to Severe Storms	<u>G. Wilson</u> /R. Jayroe
Frontogenesis Studies Using the AVE Data	D. Barber
Kinetic Energy Budgets-Intense Convection	H. Fuelberg
Ageostrophic Circulation-Severe Storms	D. Johnson/C. <u>Wash</u>
Spectral Characteristics of Mesoscale Variables	<u>G. Fichtl</u> /G. Wilson/R. Turner

X. SUMMARY (4:30 - 5:00 P. M.)

Remarks	W. Vaughan/J. Dodge/S. Tilford
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#### A. CLOUD PHYSICS RESEARCH

## SATURATOR CALIBRATION

B. J. Anderson, **ES83**  
MSFC, Alabama, **35812**  
**205-453-5218**

D. A. Bowdle, **USRA** Research Associate  
MSFC, Alabama **35812**  
**205-453-5218**

### Accomplishments, FY79:

Under this research task a method for calibration and performance evaluation of an Atmospheric Cloud Physics Laboratory (ACPL) type saturation is being developed and tested. A saturator is a device which controls the humidity within cloud physics experimental apparatus. The operating characteristics of the ACPL saturator are designed to define the water vapor mixing ratio to within  $\pm 0.5\%$ . Thus the calibration procedure must be more accurate, to about 5 parts in  $10^4$ . During FY79 the details of a gravimetric calibration method were defined and complete error analyses were made, both for the saturator and the test method. The hardware and most of the instrumentation for performing the calibration (using a laboratory prototype of the ACPL saturator) was assembled and testing was begun.

### Current Focus of Research Work:

Currently tests of the calibration method are being run with partial instrumentation. The final, high precision instrumentation will be added in a step by step manner as the operating procedure is defined.

### Plans for FY-80:

The gravimetric calibration method will be fully developed using the in-house laboratory saturator. A report will be prepared which defines the details of the method and the complete error analysis.

### Recommendations for New Research:

An alternate method based on differential pressure measurements has been defined and the error analysis completed. If unforeseen difficulties make the gravimetric method untractable this method should be developed.

## DROPLET GROWTH THEORY

B. J. Anderson  
ES83, MSFC, Alabama 35812  
205-453-5218

J. Hallett  
Dessert Research Institute  
Box 60220, Reno, NV 89506  
702-972-1676

Maurice Beasley  
Mathematics Dept. Univ. of Nevada  
Reno, NV 89507  
702-784-6773

### Accomplishments, FY79:

The classical theory of growth and evaporation of small water drops has been studied at a low level of effort for the past 10 years. A new formulation of the theory is now complete. For the first time the spherical geometry is correctly accounted for and the boundary conditions at the surface of the drop are derived from first principles in a manner which clarifies the confusion in the existing literature.

### Current Focus of Research:

The existing theories in the literature are being reviewed in the light of the new formulation and a paper is being prepared for publication.

### Plans for FY80:

The work will be terminated after preparation of a technical report and publication. The results of this study will be incorporated in other research efforts, for example, the study of ice crystal growth.

### Recommendations for New Research:

The physical insight and mathematical formulation can be applied to a number of related physical systems, particularly the nucleation and growth of ice crystals from the vapor and the behavior of atmospheric aerosols.

## RESEARCH ACTIVITIES RELATED TO ICE MULTIPLICATION

James M. Carter  
University of Tennessee Space Institute  
ES83, MSFC, Alabama 35812  
205-453-5218

### Significant Accomplishments FY-79:

Most of the research effort put forth this fiscal year has been centered around hardware performance testing and the identification of additional required hardware. This hardware is primarily for laboratory studies of the ice multiplication process. After spending considerable time on an effort to count the ice particles in the mixed phase cloud using a sugar solution inside the cold box, a decision was made to develop a system to do the counting ~~in situ~~. This system is a laser backscattering depolarization system which detects the presence of ice particles by detecting both polarizations components scattered in the backward direction from the mixed phase cloud. The science accomplishment was determining that the ice multiplication process can be modified by the addition of a surfactant (oleic acid) to the cloud. The manifestation of the surfactant effect is not totally known. This is part of the work planned for FY-80.

This investigator also took on the task of doing the controller design for a digital cassette tape based data acquisition system and a microprocessor based system. These kinds of systems are required to help manage what at times can be many sensors which one needs to record simultaneously, i.e. a large data sample or long recording times.

### Current Focus of Research Effort:

The present work is directed to getting the instrumentation in place and checked out so that the science work can be instituted at full effort shortly after the start of the fiscal year.

### Plans for FY-80:

The work outlined now for the next year entails studies of the ice multiplication process with the effort to be directed at the effect of several different variables. This work has the goal of trying to identify the physics of the multiplication process. These variables include the liquid droplet size distribution, the surface tension (addition of surfactant), addition of solid particles and riming surface properties. Another parallel task will look into charge transfer to/from riming surface.

TITLE: Warm and Cold Cloud Processes

RESEARCH INVESTIGATOR: Dave Bowdle, USRA  
ES83/MSFC, AL 35812  
205-453-5218

SIGNIFICANT ACCOMPLISHMENTS FY-79:

1. Determined sensitivity of warm cloud development to cloud condensation nucleus (CCN) spectrum using General Electric numerical simulator
2. Developed equipment for gravimetric evaluation of precision saturator
3. Determined numerical sensitivity of warm cloud initiation to carrier gas composition
4. Refined theory of activation of mixed composition CCN aerosols
5. Completed numerical feasibility study for stable drop-levitation technique

CURRENT FOCUS OF RESEARCH WORK:

1. Comparison of gravimetric and vapor pressure methods for saturator performance verification
2. Numerical solution of equations from new CCN theory, comparison with approximations

PLANS FOR FY-80:

1. Preliminary laboratory evaluation of stable drop-levitation in prototype static diffusion liquid (SDL) chamber
2. Build and calibrate precision SDL with electric field
3. Literature review of scavenging by water drops in preparation for laboratory scavenging studies in FY-81

RECOMMENDATIONS FOR NEW RESEARCH:

1. Utilize levitation techniques for investigation of other problems in cloud microphysics (Kohler theory, lightning initiation, drop growth rates, ice physics) and for evaluation of their suitability for study in low gravity.

## ICE CRYSTAL STUDIES IN A STATIC DIFFUSION CHAMBER

Researchers: Dr. Vernon Heller  
ES83, MSFC, AL 35812  
205-453-0941

Dr. B. Jeffrey Anderson  
ES83, MSFC, AL 35812  
205-453-5218

### Research Objective:

- o Identify more precisely the ambient conditions in which transitions occur in the ice crystal form.
- o Gain valuable experience in the operation of a chamber which is similar to the ACPL static diffusion chamber.
- o Gain insights which will lead to scientific advancements independent of low gravity applications.
  - \* Effect of carrier gas (thermal and vapor diffusivity)
  - \* Effect of gaseous organic contaminants
  - \* Electric field and diffusion field interactions
  - \* Simulated cirrus cloud environment
  - \* Etc.

### Accomplishments:

During FY-79 specifications were developed for a static diffusion ice chamber and a contract was let for its construction. Design is greater than 90% complete and most drawings have been received.

### Current Focus and Plans for FY-80:

- o Receipt of completed chamber from contractor
- o Interface instrumentation with chamber and calibrate chamber performance.
- o Examine ice crystal growth rates and habit changes as a function of the thermal diffusivity and water vapor diffusivity of the carrier gas in a controlled temperature, pressure, and supersaturation environment.

## GROWTH OF ICE CRYSTALS FROM LIQUID IN LOW GRAVITY (KC-135)

Researchers: Dr. Vernon Keller  
ES83, MSFC, AL 35812  
205-453-0941

Mr. Otha H. Vaughan  
ES83, MSFC, AL 35812  
205-453-5218

Dr. John Hallett  
Desert Research Institute  
Reno, Nevada 89506  
702-972-1576

### Research Objective:

Examine the effect of reduced convection on ice crystal growth from liquid.

### Accomplishments:

Equipment was designed, constructed, and assembled in-house during FY-79. Experiment was successfully flown on the NASA KC-135 aircraft the week of August 20, 1979.

### Current Focus and Plans for FY-80:

The 16 mm - movie films from the KC-135 flight will be analyzed. Low gravity results will be compared with higher gravity results. Additional KC-135 flights will be scheduled **as** required to verify low gravity results.

### Recommendation:

The NASA KC-135 aircraft can be utilized to gain insights into the effect of reduced gravity on convection in a static diffusion chamber, on particle interactions in an electric field, on wicking properties of materials, and on any number of other important phenomena which occur on a time scale compatible with the approximately 20 seconds of low gravity available in each flight parabola of the KC-135.

Title: An Assessment of Atmospheric Electrical Mechanisms for Coupling  
Solar Activity with Weather

Research Investigator: Dr. Arthur A. Few Jr.  
Department of Space Physics  
Rice University  
P.O. Box 1892  
Houston, TX 77001

Research Statement of Work:

1. Review and assess the causative chains that include as key links atmospheric electrical processes, which have been or may be hypothesized to relate an observed change in the state of the Earth's atmosphere to the Sun.
2. Form and lead the activities of a team of experts in the several disciplines involved in the causative chains.
3. Examine physical validity and probability of occurrence of links in the chains.
4. Identify gaps in hypothesized chains.
5. Formulate a program of experimental investigations.

Accomplishments FY-79:

Extensive widespread participation of the scientific community in considering atmospheric electrical processes. See listing of meetings below.

1979 Atmospheric Electrical Coupling - Team Meetings

February 9	- Cobb, Dolezalek, Olson, Few & Weinheimer
February 23	- Bering, Mohnen, Park, Wolf, Few & Weinheimer
March 9	- Anderson, Bering, Burke, Roble, Few & Weinheimer
March 14	- Cadle, Kasemir, Sartor, Few & Weinheimer
March 15	- Boulder Meeting
April 9-10	- Mid Term Review
May 30	- Goldberg, (Hale), Maynard, Few & Weinheimer
June 1	- Anderson, Dolezalek, Hoppel, Ruhnke, Willett, (other NRL scientific staff), Few & Weinheimer
June 12	- Vonnegut, Few & Weinheimer
June 18	- Grobecker & Few
July 16	- Illingworth, Orville, Vonnegut, Few & Weinheimer
July 27	- Latham & Few
August 2	- Final Review Meeting
August 16	- Markson & Few
October	- Markson
October	- Ion Chemistry
January	- AMS Special Session

**Current Focus of Research Work:**

**Preparation of a review paper on results.**

**Plans for FY-80:**

**Concentrate on detail research of more promising mechanisms.**

B. ATMOSPHERIC ELECTRICITY RESEARCH

TITLE: SEVERE STORM ELECTRICITY

PRINCIPAL INVESTIGATOR: Dr. W. David Rust, NOAA/NSSL, Norman, OK, 73069  
(405) 360-3620; FTS 736-4916

CO-INVESTIGATORS: Dr. Roy T. Arnold, University of Mississippi,  
University, MS, 38677, (601) 232-7046

Mr. William Taylor, NOAA/NSSL, Norman, OK, 73009  
(405) 360-3620; FTS 736-4916

Dr. William W. Vaughan, NASA/MSFC, ES81, Huntsville, AL, 35812  
(205) 453-3100; FTS 872-3100

Dr. Bernard Vonnegut, State University of New York at Albany,  
ES323, Albany, NY, 12203, (518) 457-4607

#### ACCOMPLISHMENTS FY-79

From the start of this research in January, we have been involved primarily with instrumentation and data acquisition, including substantial efforts to instrument a van as a mobile laboratory. Our operational program was from 1 April to 24 August. To date the major accomplishment has been the measurement of a variety of electricity parameters on nonsevere, severe, and tornadic storms, including isolated thunderstorms and squall lines. Preliminary data reduction has also begun. The types of measurements made include:

- dual Doppler, lightning discharge mapping, video, and lightning Parameters on severe storms
- lightning optical and electric field waveforms to provide basic information and relate to satellite sensor development
- electrical measurements in mesocyclone region of storms
- lightning radar echoes and associated electric field changes

#### CURRENT FOCUS OF RESEARCH WORK

We are currently involved in shifting from an operational status (as of 24 August) to data reduction and analysis. Our current focus will thus continue into FY 80 and is summarized below.

#### PLANS FOR FY 80

During the next few months, we will continue preliminary analyses of the storm data collected during the past spring and summer. We must, however, also undertake logistical preparations for next storm season, which means being ready to collect data by 1 April 1980.

Preliminary data reduction and analyses will include, but not necessarily be limited to:

- lightning optical waveforms versus characteristic features of IC and CG flashes
- lightning location versus radar reflectivity and Doppler-derived wind fields in severe storms
- VHF burst rates as a function of lightning type, altitude of lightning, etc.
- occurrence and characteristics of flashes lowering positive charge to ground
- lightning parameters in mesocyclone region
- comparison of lightning radar echoes, lightning discharge mapping, and electric field changes for flashes from a severe thunderstorm

The major logistical and hardware tasks to be accomplished during FY 80 are:

- building improved optical detectors
- instrumenting a larger van to include more instrumentation and to enhance our ability to collect the necessary data near severe storms
- modification to the lightning discharge mapping system for increased coverage
- incorporating the 23 cm radar for lightning echoes into the data acquisition scheme
- improved data reduction and analysis capability.

General plans for next year include encouraging interested colleagues to join in the spring research effort at NSSL during which storm electricity will have a major role. We currently envision making electrical measurements from April through June. After the operational season, we will concentrate upon increased data analysis.

#### RECOMMENDATIONS FOR NEW RESEARCH

No totally new research is proposed, but several areas will be expanded. Cooperative research efforts on severe storm electricity by other investigators is suggested,

Title : Storm Severity Detection (RF)

Research Investigator(s) Involved:

Dr. R. L. Johnson  
Mr. M. L. Bushman  
Division 16  
Southwest Research Institute  
6220 Culebra Road  
San Antonio, TX 78284

Significant Accomplishment FY-79:

During the period from 1 April 1979 to 1 September 1979, seventy one thunderstorm days were detected by sferic activity and monitored over an observation span of 526 hours. Sferic bursts are directionally resolved using a computer instrumented crossed baseline phase interferometer operating at 2 MHz with a 2.7 kHz bandwidth. Software was developed to provide automatic data acquisition without an operator in attendance. The system detects a thunderstorm in progress when sferic activity exceeds an empirically predetermined noise threshold and automatically logs azimuthally resolved sferic events to disc files. Notable results to date are: (1) detection of the tornadic storm in Wichita Falls, Texas on 10 April 1979. Coincident in time a large and moderately intense electrical storm was in progress approximately 250 km northwest of the interferometer site; however, the data indicated peak sferic intensity toward the tornadic activity at a distance of 500 km, (2) a large center of electrical activity was detected in the Gulf of Mexico and was later determined to be hurricane "Bob" at a range of 900 km. Data have also been acquired from other oceanic storm activity including hurricanes "David" and "Frederick."

Current Focus of Research Work

**This** program is directed toward determining whether or not HF sferic activity can be used routinely to discriminate meteorologically severe cells from non-severe cells. The HF detection frequency is chosen for long range detection and tracking of meteorologically intense storm cells. To meet **this** objective the directionally resolved sferic data are correlated with ground truth data consisting of NWS weather radar film, **GOES** satellite photos and **SELS Log** data from the Severe Storm Forecast Center in Kansas City. Concurrently, work is in progress to determine the extent land observation of sferic data and meteorological intensity can be extrapolated to oceanic storms.

### Plans for FY-80:

1. Increase the precision of cell identification using DF and satellite data.
2. Begin systematic surveillance of the *Gulf* of Mexico region.
3. Since **RF** lightning observations from space must necessarily be conducted above the critical frequency of the ionosphere, data acquisition will be made at frequencies near the critical frequency as predicted by vertical incidence soundings. Measurements will be conducted to determine whether or not the storm severity indications observed at 2 MHz are also valid at higher frequencies.

### Recommendations for New Research:

In anticipation of success in the current effort and the **FY-80** effort, the following is recommended:

1. Describe and analyze the physical mechanism(s) within the storm cell which permit long range detection by the existing phase linear DF technique. Determine the capability to recognize this phenomenon by other techniques.
2. Utilize the long range detection/location technique to correlate with results of space-borne sensors of all types.
3. Investigate the feasibility of a space-borne direction finding system for a geosynchronous satellite platform. A deployment of these sensors similar to the GOES/SM5 satellites would be appropriate to the long term effort.

Title: Remote Observations of Severe Storms

Research Investigator: Richard E. Orville  
Dept. of Atmospheric Science  
State University of New York at Albany  
1400 Washington Ave,  
Albany, New York 12222  
Phone: (518) 457-3985

Significant Accomplishments FY-79:

1. Publication of the "Global Lightning Flash Frequency" by R. E. Orville and D. W. Spencer, Monthly Weather Review, **107**, July 1979, 934-943. This paper presents an analysis of **DMSF** data between 60°N and 60°S and reports that:
  - a. The annual land-ocean ratio of global lightning at dusk ranges from 8 to 20. The midnight land-ocean ratio is 4 to 8.
  - b. The global land-ocean lightning ratio is significantly higher during northern summer than southern summer.
  - c. The dusk and midnight flash frequencies peak in the 0-20°N band throughout the year.
  - d. The ratio of global lightning flash frequency during the northern summer to that in the southern summer is 1.4 for both the dusk and midnight satellite data.
  - e. The global lightning flash frequency shows an inverse relation when compared to the published values for the annual variation of the earth's electric field.
2. Recorded spectral signatures in day and nighttime thunderstorms from 243 lightning flashes during TRIP-79 near Socorro, New Mexico. All were in the 400-700 nanometer range.
3. Analysis of the data to-date show strong H-beta and H-alpha emissions above their respective daylight background Fraunhofer absorption lines.
4. On a relative intensity scale, H-alpha is the strongest emission feature between 400 and 700 nanometers in a flash.
5. We received a lead sulphide detector in July which will extend our spectral detection capability to 1600 nanometers.
6. A calibration standard tied to an NBS standard light source has been obtained. This will allow relative intensity measurements with an accuracy of a few percent from 300 to 1600 nanometers,

Current Focus of Research Work:

1. A detailed analysis of over 300 spectra from intracloud and cloud-to-ground flashes recorded in TRIP-78 (Florida) and TRIP-79 (New Mexico) is presently underway.
2. The mapping of all lightning streaks recorded in one year by the **DMSF** satellites is presently being done in the Space Science and Engineering Center - University of Wisconsin. An analysis of these maps will be performed at SUNYA.

3. In cooperation with Dr, Robert Sax of NOAA (Miami), we plan to examine the location of cloud-to-ground flashes in a few of the **SESAME** experimental days. These data will be examined by plotting ground strike location data onto visible and infrared satellite images obtained by the Space Science and Engineering Center - University of Wisconsin, Using the **McIDAS** system, the position of ground strikes will be examined with respect to cloud growth rates and cloud top temperature.
4. In anticipation of field studies in 1980, we plan to begin a laboratory study of breakdown in air at wavelengths in the near infrared, This will provide us with the opportunity to use our optical multichannel analyzer (OMA) in the 800-1600 nm range before the next lightning season.

Recommendations for new research:

Develop an airborne spectrometer for the recording of lightning spectra from a high flying aircraft, such as the U-2. This is a natural step in the evolution of a suitable instrument to be flown on a satellite.

Title: Low-Light-Level TV Observations of Lightning Spectra

Research Investigators: K. Stuart Clifton

ES64

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C. Kelly Hill

ES84

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#### Significant Accomplishments FY79:

Spectral studies of lightning were conducted by MSFC-SSL, July 23 - August 3, 1979 as part of the Thunderstorm Research International Program (TRIP) and NASA's Severe Storms and Local Weather Research Program. The studies were made at the Langmuir Laboratory for Atmospheric Research near Socorro, New Mexico. The data were obtained with the use of low-light-level television systems supplied with transmission gratings with a resulting spectral response of 3800 Å - 8700 Å. The resulting data were recorded on video tape. The main objectives of the observations were to evaluate the use of low-light-level TV systems for future lightning research and to obtain spectral signatures of cloud-to-ground and intracloud strokes. Due to the high sensitivity of the TV cameras, little information was obtained during daytime observations. Even with the lens stopped to pin-hole size, saturation from high light levels posed a severe problem. Nighttime observations were extremely successful, however, with thunderstorms observed to a distance of 200 miles. A preliminary analysis of 4 hours and 37 minutes of data collected from three nights observation revealed a total of 484 lightning events recorded. Many of these were diffuse events or were spatially extended such that no spectral information could be extracted. However, 116 spectra were obtained of variable quality; 33 were classified as having at least several distinct lines or structures, and it is anticipated that much information can be derived from these spectra. It is felt that Langmuir studies proved that the low-light-level TV system can be a very effective tool in the observation of nighttime thunderstorm activity. It appears that such a system would be of particular value from a space-based research platform.

#### Current Focus of Research Work:

Current research efforts are involved with the reduction and analysis of the Langmuir data. This includes the logging of each observed lightning event and the preparation of an edited video tape in which each video frame of a

selected event is appropriately annotated. The analog video signal is then converted into digital format and stored on digital tape. The digital data serves as input into an Image Data Processing System (IDAPS) which is coupled to an IBM 360 computer. The data can now be manipulated in a variety of ways and the spectral lines can be identified. In addition to spectral identifications, the data will be analyzed as to frequency of events, and type of lightning (intracloud or cloud-to-ground). The results of these investigations will be reported in appropriate journals.

#### Plans for FY80:

It is proposed that ground-based observations of lightning with the use of low-light-level television systems be continued during fiscal 1980. In addition, it is proposed that the television camera be placed aboard Lear jet aircraft and flown at altitudes commensurate with the tops of thunderstorms in the area surrounding Socorro, New Mexico. Such air-borne flights should result in a larger statistical sample of intracloud lightning activity than is possible from ground based observations. It is anticipated that the spectral signatures of both cloud-to-ground and intracloud lightning strokes as seen by low-light-level TV cameras can be obtained. Furthermore, it is proposed that the spectrum of step leaders be investigated with television systems. The difficulty in obtaining such a spectrum is the faintness of the leader coupled to the brightness of the following return stroke. It is thought that low-light-level television cameras using silicon targets could be effective in this effort.

TITLE: DEVELOPMENT AND TESTING OF NOSL SYSTEM

RESEARCH INVESTIGATORS: B. Vonnegut, PI  
State University of New York at Albany  
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O. H. Vaughan, Jr., Co-I  
ES83/MSFC, AL 35812  
205-453-5218

Marx Brook, Co-I  
New Mexico Tech  
Socorro, New Mexico 87804

3. SIGNIFICANT ACCOMPLISHMENTS:

1. Through visits to Johnson Space Center and Marshall Space Center assistance and consultation has been rendered on the development of the NOSL 16 mm camera and tape recorder system to be used in the future Shuttle flights. With the cooperation of F. J. S. and J. L. at the State University of New York at Albany diffraction gratings have been furnished that will be used during the observations of lightning with the NOSL in order to supply spectral data on lightning that is occurring.

2. During the TRIP 79 Program carried out at the New Mexico Institute of Mining and Technology at Socorro field observations have been carried out using a prototype of the NOSL equipment constructed by the Johnson Space Center. Field tests indicated that there were interference problems during data collection and camera operations. The interference problem was found to be a mis-match in a control switch circuit. Flight test hardware is being checked to see if the same problem can occur.

3. In preparation for the NOSL experiment further observations have been carried out with the Bolex photocell system. Two modified Bolex cameras have been supplied to Dr. D. Rust of the NOAA Severe Storm Laboratory at Norman, Oklahoma. Data was collected using the cameras during the SESAME "79" Program and data is now being analyzed.

CURRENT FOCUS OF RESEARCH WORK:

Experiments made during TRIP-79 showed the feasibility of lightning photography by day or by night utilizing the super-8 camera triggered by either radio frequency emission from the lightning or from a photocell detected optical signal. While the super-8 sound camera in the time lapse mode is incapable of recording the details of the signal from the optical sensor, the experiments suggest that a large amount of useful data could be obtained at reasonable cost by recording the lightning with a triggered camera when it occurs and by recording the output of the photo-

electric system continuously on a cassette or reel-to-reel recorder. Identification of flashes on the camera taken on the camera film and on the tape recorder could be accomplished by visual time indications on the camera and by time code or WWV on one of the channels of the tape recorder.

**PLANS FOR FY 80:**

It appears highly desirable to obtain data and with a camera and photocell optical apparatus looking down on the top of thunderstorms, particularly those of the large severe variety that produce tornadoes. Accordingly, we are proposing to make further U2 flights with equipment of the sort used in the TRIP-79 program with emphasis on nocturnal flights and with the addition of a diffraction grating for the camera and supplementation **of** the optical data with slow antenna recordings.

**RECOMMENDATIONS FOR NEW RESEARCH:**

Thus far experimentation with the NOSL type equipment has involved the use of conventional cameras using photographic film. It appears desirable to explore the possibility of television type cameras supplemented with photo-optical equipment to obtain the signature of lightning. It would appear desirable to construct equipment of this sort to be flown on high altitude aircraft and on high altitude balloons with real time readout provided at the ground.

TITLE: OPTICAL MEASUREMENTS OF LIGHTNING USING U-2

RESEARCH INVESTIGATORS: Marx Brook  
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Otha H. Vaughan, Jr.  
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205-453-5216

Bernard Vonnegut  
State University of New York at Albany  
Albany, N.Y. 12222

SIGNIFICANT ACCOMPLISHMENTS N-79:

We were successful in programming the U-2 24 hours in advance for one flight near Langmuir lab while a thunderstorm was in progress. We have one discharge (there may be others) for which the U-2 and the ground records can be matched. The record shows an optical signal to background noise ratio which exceeds 50:1. The results are encouraging:

1. Three return strokes are easily identified
2. A number of small pulses can be associated with intracloud activity. E-field changes and radiation at 10 cm accompany the optical pulses.
3. Risetimes of the U-2 optical pulses vary from about 125 microseconds to about 250 microseconds. These results are similar to the ground based measurements.

The lightning flash discussed above is the only one we found which can be matched to our 'ground truth' records. Although the overflight lasted for about 1.5 hours in the vicinity of Socorro, the pilot wandered off to a more active storm for a part of the time.

CURRENT FOCUS:

Last fall we were provided the opportunity to instrument a U-2 aircraft for 3 flights over active thunderstorms within a 1000 mi radius of Moffett Field. A simple program of optical measurements of lightning and clouds was planned in conjunction with the TRIP '79 Program in Socorro, N. M. The principal objectives were:

1. To obtain high time resolution ( 1  $\mu$ sec) records of luminous events associated with lightning from an altitude of 65,000 feet above the clouds. This measurement was planned to help judge the feasibility of using optical signatures for distinguishing ground flashes from cloud flashes. We were concerned with the amount of light emerging from the cloud top, and with the effects of multiple scattering (multipath effects) on the risetime and duration of the pulses.
2. To record at the Earth's surface during the time of the U-2 overflights the optical emissions seen from below the cloud and to compare the

optical pulses with the electrostatic and radio frequency signals for the identification of flash type, number of strokes, etc.

3. To obtain stereo photographs (60% overlap at **30,000** feet) of the tops of growing cumulus clouds.

4. To obtain night-time photographs of lightning discharges which emerge from the cloud top and propagate in an upward direction.

**PLANS FOR IV 80:**

We conclude that aircraft flights over storms will give us the kind of information needed to study the feasibility of optical monitoring of global lightning from satellites. Additional measurements of this type are indicated. **An** electric field-change sensor should be added to the aircraft to facilitate interpretation of the events when ground measurements **may** not be available, e.g., over tornadoes or hurricanes.

Title: Lightning at the NASA Kennedy Space Center

Investigator: E. Philip Krider  
Institute of Atmospheric Physics  
University of Arizona  
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-1211

Abstract: Multi-station measurements of the total change in the thundercloud electric field can be used to detect and locate lightning. The spatial and temporal evolution of lightning during three storms at the Kennedy Space Center will be presented in a short motion picture,

Title: Recent Advances in the Detection of Cloud-to-Ground  
Lightning

Investigators: E. P. Krider, A. E. Pifer, and M. A. Uman  
Lightning L. & P., Inc.  
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Abstract: Extensive networks of lightning detection systems have been installed throughout the western United States, Alaska, and Canada to facilitate the detection of lightning-caused forest fires. Other systems have been installed for research in atmospheric electricity and for evaluating the effects of lightning on electric power distribution systems. Several Examples of the system outputs during the summer of 1979 will be discussed,

THE PHYSICS OF RF RADIATION FROM LIGHTNING  
FOR  
APPLICATION TO REMOTE SENSING OF SEVERE STORMS

INVESTIGATOR: D. M. Le Vine  
NASA/Goddard Space Flight Center  
Code 946  
Greenbelt, Maryland 20771  
301-344-8059

ACCOMPLISHMENTS:

o TRIP-79: Two weeks at Langmuir Laboratory yielded data from two close storms. Simultaneous measurements of fast electric field changes and RF radiation were made for comparison with similar measurements made in Florida. The comparison will test hypotheses concerning the origin of RF radiation during return strokes.

o MODELLING: A theory has been developed which explains the radio frequency spectrum of radiation from return strokes. Channel tortuosity appears to play an important role at HF and VHF frequencies ("The Influence of Tortuosity on the Spectrum of Radiation from Lightning Return Strokes," NASA TM-79544, Le Vine).

o SOURCE OF STRONG RF RADIATION: Experiments during TRIP-78 indicate cloud processes as sources of very strong RF radiation. The strongest RF radiation of all appears to come from an unusually fast intracloud event with many characteristics of a K-change ("Sources of the Strongest Radiation from Lightning," NASA TM-80265, Le Vine).

o FLASHING RATE STATISTICS: Flashing rate statistics from several storms in Florida have been analyzed. Simultaneous occurrence of flashes is important for active storms. With overlapping taken into account, both data and theory suggest a lognormal density function for the time between flashes ("Rate Statistics of Radio Noise from Lightning," Le Vine, Meneghini, and Tretter, National Radio Science Meeting, USNC/URSI, June 1979).

FOCUS OF PRESENT RESEARCH:

This research program focuses on determining the characteristics of RF radiation from lightning (amplitude, spectrum, etc.) and at understanding the mechanisms responsible for its production. Ultimately, we are interested in establishing the relationship between the signal detected by a sensor (perhaps in space) and the parameters of the lightning which produced that radiation. We feel that this *is* an important step in developing lightning as a tool for severe storms research.

## PLANS FOR FY80:

o INVESTIGATION OF CLOUD PROCESSES: Previous experiments have identified cloud processes as significant sources of strong RF radiation. Experiments are planned to improve our understanding of cloud processes and to characterize RF radiation from them.

o SPECTRAL MEASUREMENTS (RF): Measurements are planned to provide additional information about how the RF signal from lightning depends on frequency. Since a lightning flash consists of many distinct events, we propose to: a) examine first return strokes and compare measured spectra with theories suggesting a dependence on channel tortuosity, and b) determine how the spectrum of return strokes is related to the spectrum of other events.

o IDENTIFICATION OF FLASH TYPE: Evaluate data sets from TRIP to determine how reliably flash type (C-G or C-C) can be determined from its RF signature and whether this is feasible from space.

## NEW RESEARCH:

o RF MEASUREMENTS AND LIGHTNING PHOTOGRAPHS: The GSFC research program has produced significant evidence that channel tortuosity is important in determining radiation from lightning. Simultaneous photographs of channels and RF measurements would be a big step toward verifying these hypotheses and understanding mechanisms responsible for RF radiation.

o COMBINED RF AND OPTICAL SIGNAL MEASUREMENTS: High time resolution measurements of RF radiation and fast electric field changes have been productive in providing insight about the physics of RF radiation. It is proposed to repeat these measurements adding an optical channel. The emphasis here is to be on high temporal resolution (e.g., using digital sample-and-hold devices) investigation of single events so that time delay and rise time can be measured.

o EVALUATION OF INTERFEROMETRIC TECHNIQUES FOR MONITORING LIGHTNING FROM SPACE: This is to be a comparative study of several different techniques (amplitude and intensity interferometers, and multiple frequency correlation) for detecting lightning from space. Simulated electric field waveforms would be used to assess performance.

## AIRCRAFT MEASUREMENTS

### Ralph Markson

Airborne Research Associates	and	Mass. Inst. of Technology
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Weston, Mass. 02193		W-91-206
617-899-1834		Cambridge, Mass 02139
		617-253-2708

The support from NASA this summer at Socorro was to gain experience operating the modified movie camera developed by Bernard Vonnegut and NASA (~~as~~ the **NOSL** camera) from a high flying aircraft. This camera records the presence of lightning in the field of view as clicks on the soundtrack when a photocell senses electromagnetic radiation emitted by the lightning. The objective of the field testing was to simulate, as much as possible from an aircraft, the view and operating conditions that the astronauts will experience when utilizing this camera on the Space Shuttle. Human factors and operational problems were to be evaluated, as well as the camera's ability to sense and record lightning which is generally invisible to the eye (particularly in daylight).

Thunderclouds were photographed on six flights by three different operators (O.H. Vaughan, J. Sedlacek and R. Markson). Also, some thunderstorm clouds were photographed from the ground. Both the early model (modified Bolex) and NASA developed (**NOSL**) cameras were utilized. The major operating difficulty proved to be in hearing the clicks on the audio monitor over the high ambient noise level (similar to what will be on the Shuttle). While preliminary analysis indicates some lightning clicks were recorded, most of the film has not been processed yet and it is not known what was recorded. All films and logs have been delivered to O. H. Vaughan who will do the analysis.

During these flights, as a secondary objective, measurements were also made of electric fields and conductivity using new instrumentation which is still under development. A new corona point system was designed and underwent preliminary testing. It appears to work and offers the possibility for measuring thunderstorm intensity electric fields near, as well as within, clouds with relatively cheap, light and simple instrumentation. In addition, new design conductivity tubes developed by B. Vonnegut were operated on an aircraft for the first time and worked well in clear air. (No conductivity tubes will work within clouds).

Because of operational problems with the engine and turbocharger,

combined with the fact that the thunderstorms generally did not become electrified until they topped out in the low 30,000 ft. height range, we could not fly over the anvils. My primary research objective relative to the study of thunderstorm electrification, has been to measure the condition current over the tops of anvils and to relate this to cloud top structure (turrets) because there is reason to believe that a "screening layer" at the cloud surface strongly controls the charge flowing between the cloud and the region above it. After several years experience in the TRIP program using a modified Bellanca single engine aircraft, it has become clear that an aircraft with a higher ceiling is necessary for this research. The most practical aircraft, considering operating cost, flexibility of operation, load carrying ability and performance would be a turbocharged Beechcraft Baron. Standard versions of this twin engine propeller driven aircraft have been routinely flown at 37,000 ft and had some climb capability left at that altitude. With stretched wings (2 m span) as on the present aircraft the Baron should reach 40,000 ft which is sufficiently high to top most thunderstorms at Socorra and in many other regions. Going any higher in a non pressurized aircraft is not safe or practical because of physiological factors.

This proposed aircraft would serve as a platform for several related complementary investigations. Tentative plans include besides the conduction current-cloud top structure measurements (using electric field, conductivity, infra red cloud top temperature and photography), lightning VHF observations with an interferometer (J. Warwick), lightning optical observations (R. Orville) and lightning low light level observations (S. Clifton). Being able to carry this array of sensors to thunderstorms in different regions (Alaska, SW United States, maritime storms) and the flexibility of operation with the investigators controlling the aircraft and instrumentation would offer a unique opportunity to study thunder storm electricity in a highly cost effective flight program.

Such observations are important to the study of severe storms because they would allow:

1. Comparison of various sensing techniques to help in deciding which lightning detection techniques should be used on satellites. Possibility of "ground truth" comparisons with satellite sensors.
2. Views of thunderstorm tops from the perspective of satellites.
3. Evaluation of the relationship of lightning intensity and

occurrence with the overall electrical generating output of a thundercloud. The only reliable way to measure this is above the storm where only a conduction current flows; this must be the sum of the numerous currents flowing through various processes between the earth and base of the thundercloud.

4. Study of the relationship of cloud top structural electrification, e. g., if the screening layer controls the transfer of charge between the cloud and upper atmosphere it would follow that only clouds with boiling turrets are effective generators of electricity and the cloud structure as observed from above would be a diagnostic tool since electrification appears to be associated with severe storms. Similarly the height of cloud tops is probably highly correlated with the electrification of the clouds and this relationship could be determined with the proposed measurements.

5. Study the relationship of lightning in the clouds (detected by the interferometer and possibly a photocell array or scanner) to the intensity and location of precipitation within the clouds (determined by the aircraft's "storm avoidance" radar), This ultimately could lead to better techniques for aircraft to avoid dangerous parts of cumulus clouds.

Title: Atmospheric Electricity Models

Research Investigator: L. W. Parker  
Lee W. Parker, Inc.  
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Concord, Mass. 01742  
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Significant Accomplishments FY-79:

Surveyed prominent models of cloud electrification in order to shed light on question of how modeling and experimentation can be used for interpreting satellite (or ground) observations of lightning in terms of the likelihood of severe storms or dangerous convective patterns.

Organized models in classes ("precipitation", "convection", and "general"), in terms of their strengths and weaknesses, and what they can and cannot do. Considered the nature of their inputs and outputs, the various changing mechanisms, dimensionalities, and degrees of sophistication.

Participated in TRIP/79 at Socorro, visited NCAR and South Dakota School of Mines and Technology, discussed various aspects of the theory-experiment interaction with experimenters and theorists. Surveyed information on instrumentation relevant to modeling.

Current Focus of Research Work:

Distilling and refining results of survey. (See Attached tabulation of prominent models and their characteristics.) Updating data through personal contacts. Preparing report and recommendations.

Plans for FY-80:

Plan to investigate screening layer dynamics with more precision than available to date. This is a significant gap in the models available, and must be covered in order to theoretically study the Vonnegut concept, and interactions between convection and electrification more generally.

### Recommendations for New Research:

Besides improving screening-layer theory, put more sophisticated microphysics into the general models. Another recommendation is to provide "modular modeling" software for experimenters, and perhaps also a "retrospective modeling" capability using well-documented circulation and water distributions with time. A final general recommendation is to do whatever is possible to more strongly couple modeling and experiments.

TYPE	NAME	DIMENSION- ALITY	CIRCULATION/ CLOUD DYNAMICS	ELE
GENERAL	CHIU/HELSDON/ ORVILLE	R-Z, X-Y	SOPHIST. EQS. OF MOTION (WARM)	WILSON + POLAR.-IND. (NO SPECTRA)
GENERAL	PRINGLE/ORVILLE	X-Y	"	CLOUD= + RAIN = - (NO SPECTRA)
GENERAL	LIBERSKY/PETSCHEK	X-Y	"	NONE
PRECIP	KUETTNER ET AL	X-Y	ASSUMED CIRC. SIMPLE VORTEX + SHEAR	SOPHIST. COLLI- SIONAL MICROPHYS. (SPECTRA)
PRECIP	ILLINGWORTH & LATHAM	"1-D" R-Z	SIMPLE UPDRAFT	"
				" (WARM)
CONVEC- TION	CHIU & KLETT	R-Z	ASSUMED CIRC, (GUTMAN)	COWVECTIVE (NO PRECIP)
CONVEC- TION	RUHNKE	R-Z	ASSUMED CIRC. SIMPLE VORTEX	CONVECTIVE (NO PRECIP)

RESEARCH ACTIVITIES  
AUBURN UNIVERSITY

**Analytical/Experimental Support for  
Determining the Feasibility of Detecting  
and Measuring Lightning Discharges  
from a Space Platform**

Thomas H. Shumpert  
Martial A. Honnell  
Electrical Engineering  
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FY-79 Accomplishments

Extensive literature search and preparation of review paper for lightning workshop

Presentation of review paper entitled "The State of Technology in Electromagnetic (RF) Sensors (for Lightning Detection)" at NASA/UTSI Workshop on the Need for Lightning Observations from Space

Participation in workshop as member of the Electromagnetic Techniques Committee

Set-up lightning observation station at Auburn University which includes VLF (~7kHz) orthogonal loops for directional information, remotely directed VHF and UHF antennas and broadband receiver for spectrum information from 20MHz to 2GHz, remotely directed SHF antennas and narrow-band receivers for spectrum information from 2GHz to 30GHz

Current Focus of Research  
and Plans for FY-80

Continued development of and improvement in data measuring facilities and capabilities for the detection and identification of lightning characteristics

Data collection and spectrum analysis of VLF, UHF, and SHF lightning emissions

Investigation of polarization characteristics vs spectrum characteristics

Scatter properties of commercially generated signals (AM, FM, TV, etc.) by ionized channels

Lightning-induced interference in communication satellites uplinks

Numerical investigation of strengths and characteristics of signals at synchronous/nonsynchronous altitudes produced by pseudo-arbitrary ionized channels

Numerical prediction of scatter properties of commercial signals by pseudo-arbitrary ionized channels

Range/position determination schemes utilizing ionized channel scatter of locally transmitted signal (generalized monostatic and bistatic radar considerations)

Correlation with and utilization of sensors, detection schemes, and data collected by electromagnetic pulse (EMP) community

#### Recommendations for New Research

Accumulate (with ready availability to all investigators) an extensive data base of actual recorded lightning emissions including sensor-system characteristics

Repeated analysis of data base for common data characteristics distinguishing stroke type (intracloud or cloud-to-ground), storm type/severity (rain, hail, tornadic, etc.), or other definitive parameters

Establish one or more synchronous platform RF sensors with different threshold levels for determining baseline signal strengths at synchronous altitude

Support all (as many as possible) space-based observations with ground truth measurements

Improve existing models and generate new models for simulating lightning-produced emissions

Seriously investigate "active" vs "passive" sensor/detection systems

## RESEARCH ACTIVITIES

TITLE: Lightning Mapper Feasibility Study

RESEARCH INVESTIGATORS:

Wayne Wagon, MSFC (EC31) 453-4623  
Warren Harper, MSFC (EC31) 453-4621  
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SIGNIFICANT ACCOMPLISHMENTS IN FY-79:

Following the "Workshop on the Need for Lightning Observations From Space" held February 13-15, 1979, considerable time was spent studying, organizing and evaluating the requirements that were presented by the scientific and applications (user) communities. The purpose of this activity is to arrive at a comprehensive set of requirements together with their associated rationale, data formats, accuracies, etc. Several detector types were selected for investigation to determine characteristics, performance and applicability for lightning detection. Video recording equipment was assembled for recording lightning flashes for further study and evaluation. Two excess antenna mounts were located at KSC and their transfer requested to MSFC. A review was made of current test facilities and assessed against future requirements. A matrix of sensor system requirements was initiated. An overview of the RF frequency spectrum was conducted with emphasis on potential windows (bands) for a satellite system. A study was initiated to define potential flight opportunities aboard aircraft and balloons. A plan was developed for the Science and Application Team for proposal development.

Current Focus of Research Work

Efforts are being made to expedite the transfer of the two antenna mounts from KSC. The requirements matrix is being revised based on recent information that will make it more useful. Video recording of local lightning in thunderstorms continues. The recently purchased equipment for test, evaluation and calibration of radiation sources and detectors is being checked out and set up for laboratory operation. A list of needed technical support is being finalized. Plans continue in the formulation and organization of the Science and Application Team to be responsible for the generation of a technical proposal during FY-80. Investigations of aircraft and balloon flight opportunities continue. Numerous meetings and coordination sessions are being held to formulate and document the several tasks that will be required

during **FY-80** to support the inhouse study activities- Literature surveys of specific measuring programs is a continuing activity. Inhouse test plans for various detector types, gratings, antennas, receivers, etc. are still being worked and updated.

#### Plans for **FY-80**:

The majority of the effort in **FY-80** will be organized in two areas with both supporting a single objective- The two areas are the inhouse activities (studies, trade-offs, tests, evaluations, modeling, documentation, etc.) and the contracted activities to support the inhouse program- The primary objective is to **arrive** at a preliminary proposal in May and a final proposal in August to be submitted to Headquarters. It is anticipated that all these activities will provide a basis for the development and preparation of a proposal ~~that~~ will contain the requirements for a sensor system to satisfy the maximum number of users. To support the proposal, several trade studies will be conducted, various detectors will be evaluated, models will be developed and exercised, tests will be performed to satisfy certain data requirements and most important of all the proposal will contain the input and critical review of the best experts in the field.

#### Recommendations for New Research:

It is recommended that research (or additional research) be conducted in the following areas:

- a) Numerical modeling of lightning characteristics in order to predict and understand better the measurements now being made.
- b) Investigate the relationship of thermal gradients to lightning paths in thunderstorms.
- c) Support instrumentation on a platform to complement a lightning sensor.

## RF INTERFERENCE AND PROPAGATION PROBLEMS APPLICABLE TO A SATELLITE LIGHTNING SENSOR

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### Significant Accomplishments FY-79

Our efforts to date have been modest, and concentrated on a broad-brush, preliminary survey to identify the rf noise and propagation elements possibly affecting the design and operation of a satellite **rf** system for lightning detection, measurement and monitoring.

At present, it appears that frequencies in the **VHF** and **UHF** bands offer greatest promise for minimizing deleterious propagation effects. Below **30** MHz the ionosphere imposes severe effects (eg, absorption, scattering, refraction), and above 3 GHz the atmosphere plays an increasingly greater part in signal attenuation and scattering. Unfortunately, the characteristics of both the desired lightning signature and the undesired background noise are less well known in the VHF/UHF bands than in lower frequency bands, **so** some tradeoffs will likely be necessary.

Above the ionospheric critical frequency, signals from terrestrial transmitters (eg, communications, radar, broadcast) penetrate into space with such high intensity that it will be imperative to select operational frequencies in protected bands, such as the guard bands of standard time transmitters **or** the radio astronomy bands.

### Current Focus of Research Work

We are presently gathering data and information relevant to the problem at hand, in preparation for conducting more detailed study than that possible to date.

### Plans for FY-80

Based on the results of the aforementioned modest survey and the recommendations of the Tullahoma Workshop (Christensen et al, 1979), we plan to address noise background and propagation effects in greater detail in the coming fiscal year.

Noise sources, their relative importance and spatial distributions need to be identified. Also, the source radiation characteristics must be established in terms useful for the definition of system design requirements. The characteristics of interest include the spectral distribution, spectrum occupancy, spatial and temporal variations, amplitude and time statistics, polarization, directionality, and waveforms. (Background data **for** ground-based man-made radio noise is given in Herman (1979).)

Known propagation effects that need to be considered include absorption, refraction, reflection, scattering, focussing, dispersion, Faraday rotation, distance attenuation, and temporal/spatial variations. Also, the effects of

scintillation should be investigated, as this represents an unknown quantity at present. VHF/UHF signals (up to at least 6 GHz) transmitted from satellites to ground suffer severe scintillation due to ionospheric irregularities, especially in auroral and equatorial latitudes. If reciprocity holds in trans-ionospheric propagation, as we assume it does, the terrestrial radiations received at the satellite will be similarly affected. Whether or not the effects will be severe enough to mask a desired lightning signature needs to be ascertained.

Once the radiation characteristics and propagation effects are established, the received signal characteristics at the lightning-detection satellite can be described for the undesired background, and to some extent for the desired lightning signal as well.

The body of information thus generated will serve as a basis for definition of the design and operational requirements to be imposed on the rf system for lightning detection.

### Recommendations for New Research

Considering that the FY-80 effort will establish bounds on the system for normal operational requirements, it appears that follow-on research in the following areas will help to optimize system performance:

1. Refinement of transient noise and interference characteristics to provide for development of hardware or software techniques designed to minimize "false alarm" rate, and/or rejection of contaminated data.
2. Analysis of rf data from existing satellites to obtain in situ estimates of background noise and interference for comparison with projected results from extrapolated ground-based data.
3. Utilization of rf lightning and noise data from ongoing ground-based programs for frequencies especially above 100 MHz to refine the estimates of background noise and desired signal characteristics at satellite altitudes of interest.
4. Comparison of ground-based rf lightning measurements (e.g., flash counters) with satellite optical measurements for "ground truth" assessments.
5. Comparison of previous satellite optical and rf measurements of lightning and severe storms to determine the probable performance of a combined optical/rf system.

Additionally, it appears that meteorological considerations alone are inadequate to make accurate predictions of the formation, growth and subsequent movement of severe tropical disturbances. It would therefore be interesting to investigate the possibility that electrical forces might play a role,

Using instrumented aircraft, the comparative electrical activity associated with tropical depressions, tropical storms, and hurricanes could be established. Atmospheric electrical conditions in the vicinity of and at times of these sequentially developing phenomena should also be investigated.

### References

- Christensen, L.S., W. Frost, and W.W. Vaughan (1979). Proceedings: Workshop on the Need for Lightning Observations from Space, held Feb. 13-15, 1979, at the University of Tennessee Space Institute, Tullahoma, Tennessee.
- Herman, John R. (1979). Electromagnetic Ambients and Man-Made Noise, Vol. III of Multi-Volume EMC Encyclopedia Series, Don White Consultants, Inc., publisher, Gainesville, Virginia 22065.

Title: Lightning Mapper Optical Team Plans

Investigator: Dr. William Wolfe  
University of Arizona  
Tucson, AZ 85721

Design Attempts:

A. Using a single chip (TI **800x800, 20**  $\mu\text{m}$ )

1. Global **-19<sup>0</sup>**, 15 km
2. Conus **+**, 8 km
3. Best Resolution (1-4 km)

B. Multiple chips, varied chips

1. Global, best resolution

C. Linear Array

1. Define problems

D. Spectral Analyzer

$$\Delta x = 50\text{A}, \Delta t = 2\mu\text{s}, \Delta x \gg 10 \text{ km}$$

Design Issues:

A. CCD properties

B. Background discrimination

1. Spectral
2. Temporal
- 3. Spatial**

C. Pointing accuracy

D. Data Handling

E. Combined systems

OUTLINE OF RESEARCH ACTIVITY  
for  
NASA/MSFC FY-79 SEVERE STORMS AND LOCAL WEATHER RESEARCH REVIEW

TITLE: Measurements of in-cloud electrical parameters during thunderstorms by a balloon-borne coronasonde in support of the Atmospheric Electricity (lightning) and Cloud Physics Program at MSFC.

INVESTIGATOR: Michael Susko, ES84  
Atmospheric Sciences Division  
Space Sciences Laboratory  
Marshall Space Flight Center  
Huntsville, Alabama 35812

PHONE NO. : 453-3103

SIGNIFICANT  
ACCOMPLISHMENTS  
FY79

1. An AMT-4B radiosonde was modified by replacing its humidity sensor with a coronasonde circuit. The coronasonde was flown during the May 4, 1979 thunderstorm in Alabama. This was reported in a memo: "Coronasonde Used to Obtain In-Cloud Electrical Measurements During Thunderstorms."
2. A survey of the literature was made and reported as follows: "A Survey of Some Electrical Atmospheric Measurement Techniques."

CURRENT FOCUS OF  
RESEARCH WORK

Satellite and radar plan-position indicator (PPI) data which illustrate the thundercells are being analyzed. These data added to the coronasonde's electrical measurements of positive and negative charges versus altitude and the rawinsonde data of wind direction and velocity offers considerable promise in lightning and thunderstorm research.

PLANS FOR FY80

1. During a thunderstorm, 4 coronasondes will be released about an hour apart from MSFC's Atmospheric Research Facility. The rawinsonde system will be used to track the balloon-borne coronasonde. Plots of altitude versus temperature, corona current from the coronasonde, wind speed and direction will be measured using the Rawin System.
2. During the thunderstorm, the following data sources will be incorporated into the analysis.
  - a. Interpret and analyze the meteorological data, the general synoptic and local atmospheric conditions.
  - b. Interpret and analyze the radar plan-position-indicator (PPI) data during the thunderstorm.

c. Interpret and analyze satellite data during the thunderstorm.

RECOMMENDATIONS FOR  
NEW RESEARCH

Since the data from this research is just a point on the global scale, the need to understand the global picture of the mechanisms that go into the production of severe **storms**, lightning and tornadoes is necessary. Some of the existing questions are: Can small clouds produce lightning? Can warm clouds produce lightning? Also, in the middle latitudes, not much is known about lightning associated with frontal storms. Better correlation between **atmospheric** electricity and storm systems will lead to improved prediction.

Since correlation between lightning and precipitation processes, between lightning and convection, and storm severity are necessary, observations from space and ground truth data from the coronasonde may answer some of the above questions.

### **C. MESOSCALE/STORM DYNAMICS RESEARCH**

## Ionospheric - Severe Storm Coupling

### Investigators:

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Ru J. Hung  
University of Alabama in Huntsville, AL 35807  
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George S. West  
ES83, Marshall Space Flight Center, AL 35812  
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For the past several years we have been monitoring the F -region of the ionosphere with an HF CW Doppler Array located in North Alabama. The system is described in detail in another paper (G. S. West) in this document. A typical data record is shown in Figure 1. These data are subjected to both spectral and cross-correlation analyses to identify the characteristics of the wave perturbations that are contained in the observational data. Our earliest results confirmed those of other investigators that waves with periods of 3-5 and/or 7-9 minutes were present when thunderstorms with tops that penetrated the tropopause were nearby. As our research activities continued we found that waves with periods of 10-15 and/or 25-30 minutes were present when tornadoes were occurring. We also had an opportunity to analyze data that contained waves which we were able to associate with Hurricane Eloise. These waves had periods of 25-30 minutes also.

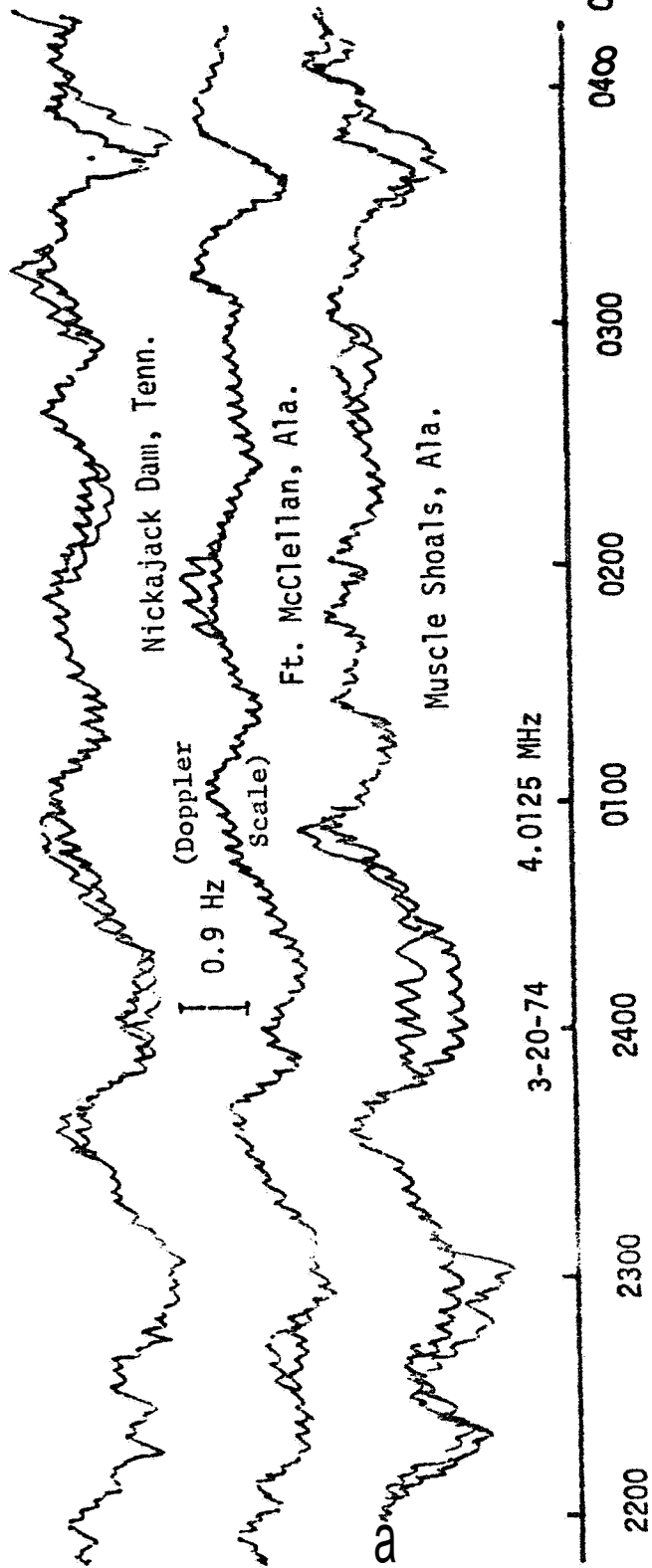
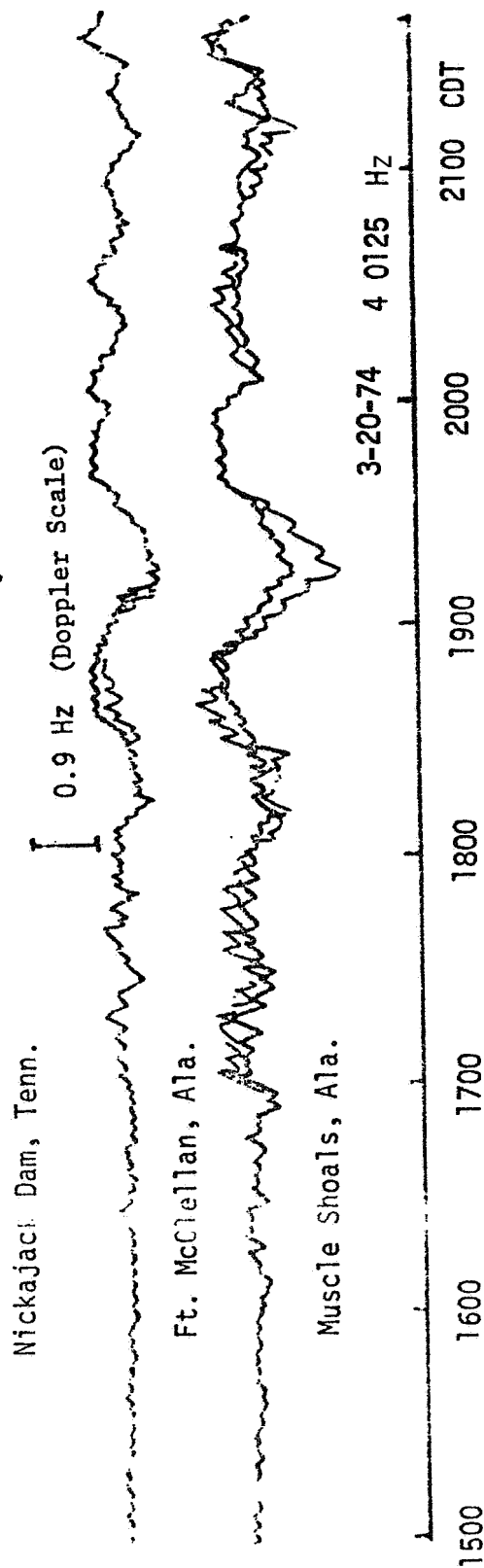
We added a reverse ray tracing computation to our data analysis technique and subsequently were able to identify the probable locations of the sources of these waves with the 10-15 and 25-30 minute periods. In all cases analyzed the waves were generated at locations where tornadoes touched down more than one hour later. Our continued analyses of NOAA radar maps, weather maps, and GOES/SMS satellite cloud imagery showed that these source locations were where convective storms had penetrated

the tropopause and convective overshooting turrets were present. However, there were other areas where overshooting turrets were present that did not generate these waves • and tornadoes did not occur either, We have shown that overshooting turrets are a necessary condition. Now we are trying to identify the sufficient conditions.

Complete data sets suitable for these analyses are fairly rare. The data set for the May 29, 1977 Oklahoma tornado is suitable and our analyses will be directed toward identifying the waves with 3-5 and/or 7-9 minute periods from the thunderstorms preceding the tornado and then attempting to identify some precursor signal that would warn when the waves with 10-15 and/or 25-30 minute periods were going to start, Another paper in this document (R, J. Hung) describes the status of our current studies on this storm.

The data set for January 13, 1976 should also be examined in more detail. On this day there were two squall lines with almost identical radar and weather maps signatures. The northern squall line through Illinois and Indiana generated waves with 25-30 minute periods and several tornadoes while the southern squall line through Mississippi did not generate either waves or tornadoes. This study has the potential for providing answers to the questions of what is sufficient for tornado generation.

Since the waves are generated prior to tornado touchdown, our research activities will also continue to investigate the feasibility of an advance warning system; however, at the present time obstacles to development of such a system are large and solutions not too apparent. We hope that our efforts will uncover new signals which can be used to implement an advance warning system.



CW Doppler record at the operating frequency of 4.0125 MHz (event on March 20, 1974)

TITLE: IONOSPHERIC REMOTE SITES AND OPERATIONS

PRINCIPAL INVESTIGATOR: George S. West, Jr., NASA/MSFC,  
ES83, 205-453-1557

#### ACCOMPLISHMENTS FY-79

During 1979 plans have been tentatively formulated for acquiring a remote site located adjacent to UTSI at Tullahoma, Tennessee. This site acquisition would give the system better coverage especially for severe storm phenomena. Further, during 1979, action for needed hardware for testing of a new method of transmitter operation and data handling have been made.

#### CURRENT FOCUS OF RESEARCH WORK

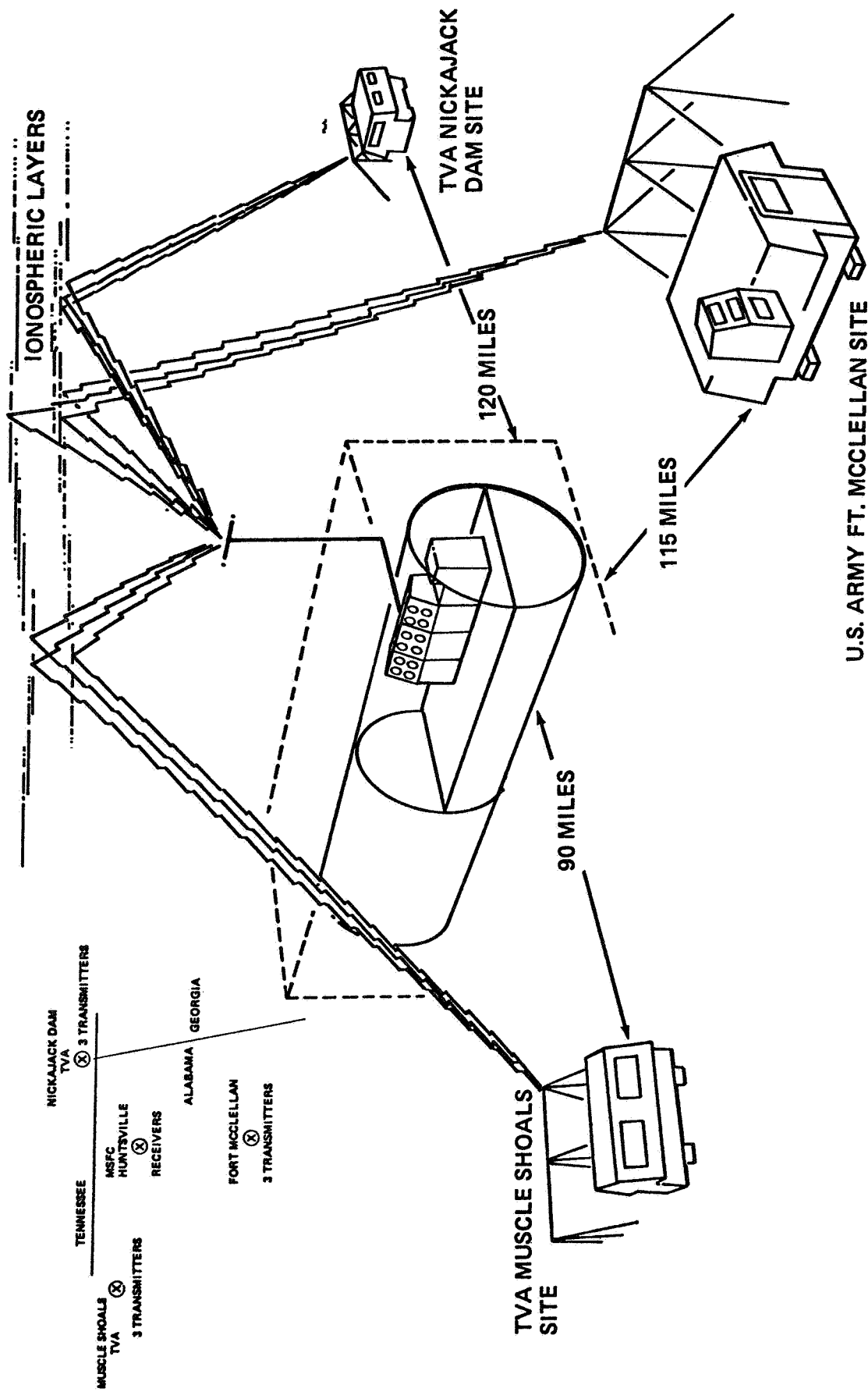
The current focus of research work is on severe storm data acquisition.

#### PLANS FOR FY80

Continuation of the work now in progress and improvement of the system which is now underway.

#### RECOMMENDATIONS FOR NEW RESEARCH

New research in addition to the continuing work of Dr. Hung, UAH will be undertaken by Dr. Balachandran, Lamont-Doherty Geological Observatory with his data acquisition systems. Both the MSFC system and the Lamont System will exchange data and results particularly on specific disturbances monitored by both systems.



IONOSPHERIC DOPPLER SYSTEM TRANSMITTER-RECEIVER ARRANGEMENT

**Title:** Acoustic and gravity waves in the neutral atmosphere and the ionosphere, generated by severe storms.

**Investigator:** Nambath K. Balachandran, Lamont-Doherty Geological Observatory of Columbia University, Palisades, N. Y. 10964  
Phone: 914-359-2900, x 355.

**Significant Accomplishments EY-79:** The project started at the end of April 1979. Infrasonic signals from a few thunderstorms have been recorded. The dominant part of the vast majority of signals is a rarefaction; in agreement with the theory of the generation of sound due to the collapse of the electrostatic field. The dominant rarefaction pulses have periods in the range of 0.4-1 sec. with amplitudes of the order of  $1 \text{ N/m}^2$ . The signals are found to be highly directional; beamed almost straight down from the source.

A detailed case study of gravity waves generated by severe thunderstorms has been completed. Thunderstorms with tops, as detected by radar, up to 58,000 ft. in the Eastern Ohio-Pennsylvania area generated gravity waves which propagated generally to the east. The waves consisted of a pressure pulse with a duration of about 4 hours (with an increase of pressure of more than 3 mb in 15 min.) as well as sinusoidal oscillations with periods in the range of a few minutes to a few hours. The pressure pulses were detected by standard weather bureau microbarographs and the quasi sinusoidal higher frequency oscillations by more sensitive microbarovariographs. The waves were associated with the cold outflow of the dissipating thunderstorms. The waves travelled long distances of the order of a 1000 Km. It is found that the waves travelled with a velocity equal to that of the wind just below the tropopause level. The propagation was found to be non-isotropic--no waves were detected to the west of the generating area since the wind at the tropopause level was westerly. The layer below the tropopause was found to be conditionally unstable; this condition along with the critical level (steering level) produced ducting conditions for the waves.

The gravity waves generated new thunderstorms along their path. Thunderstorms were reported at various stations soon after the passage of the waves. For example, New York radar reported thunderstorms with echo-tops up to 38,000 ft. in the vicinity of Harrisburg, Pa., roughly an hour after the passage of the waves at that station. Varying amounts of rainfall were reported from stations all along the route of the waves. Strong wind shifts were also reported. A crude calculation of the wave phase velocity employing the impedance relation for gravity wave, with the use of windshift as orbital speed due to the waves and the pressure change (perturbation) recorded on the microbarograph, gave good agreement with the observed phase velocity,

There seems to be clear evidence, in the present case, that the gravity wave did trigger thunderstorms--the propagating wave was very distinct from the pressure effects associated with the development of new thunderstorms. Also, the wave was not dissipated by the convective activity, the wave progressed without significant change in shape or amplitude to generate new storms in areas with proper distribution of temperature and humidity.

Current Focus of Research Work: The current objectives are, establishment of the Dopplersounder array and collection of ionospheric data; analysis and interpretation of infrasound signals from thunder, and analysis and interpretation of gravity wave data at ground level. Satellite pictures are studied for each gravity wave case to determine gravity wave parameters at the cloud level, whenever conditions are appropriate,

Plans for FY-80: During this period we plan to complete the establishment of the 3-dimensional array of Dopplersounders. The propagation of acoustic signals of thunder from the troposphere into the ionosphere will be studied. The other aspect of the ionospheric program will be the detection of gravity waves from severe storms. Ray tracing techniques will be employed to locate the tropospheric source of the waves and relationship with severe storms. The data will be compared with the data from the NASA Dopplersounder array at Huntsville. Satellite pictures and film loops will be employed to study the wave characteristics between the ground level and ionospheric level.

A new array of microphones will be established to locate the position and study the movement of the source of the infrasonic signals from thunder. Theoretical studies with appropriate models of the charged region to explain the characteristics of the observed signals will be undertaken. Installation of an electric field mill and study of the relationship of the electric field and infrasonic signals will also be made.

On the gravity wave aspect, we will extend the work on the triggering of severe storms by gravity waves. Satellite pictures and film loops will be employed.

Recommendation for New Research: (1) Relationship of the charge distribution and electromagnetic radiation on the source and characteristics of infrasound signals from thunder,

(2) Lightning superbolts have been detected by satellites. Infrasound signals generated by such lightning should be studied along with ionospheric effects.

(3) Coordinated study of Doppler radar, ground level microbarographs, Dopplersounder and satellite data to determine if the Dopplersounder with any other data source could be effective in predicting the touchdown region of tornadoes.

Title: Gravity Waves and Severe Storms

Research Investigators:

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Significant Accomplishments FY-79:

Ionospheric Doppler sounder observations during the time periods with severe storm activity show a coupling between the troposphere and the ionosphere. It has been well-recognized that gravity waves can be excited by penetrative convection. Our study reveals that gravity waves associated with severe storms are excited at the squall line and in isolated clouds with enhanced convection in which Gossard and Sweezy (1974), Stull (1976), etc., have suggested that these mechanisms could excite gravity waves.

Three types of gravity waves associated with tornadoes have been analyzed. These three types are as follows: (1) gravity waves associated with a group of tornadoes (e.g., April 3, 1974 tornadoes in mid-eastern United States); (2) gravity waves associated with isolated tornadoes with the presence of a squall line (e.g., January 13, 1976 tornadoes in Indiana, and November 20, 1973 tornadoes in Mississippi, Arkansas and Louisiana); and (3) gravity waves associated with isolated tornadoes without the presence of a squall line (e.g., May 29, 1977 tornadoes in Oklahoma).

Ray tracing computation was carried out to identify the location of the gravity waves detected at the Doppler sounder records. Based on more than thirty cases of analyses for three types of gravity waves mentioned earlier, it is found that the wave sources of gravity waves associated with tornadoes were always located on the squall line and/or isolated clouds with enhanced convection where the tornado touched down more than one hour after the gravity waves were excited.

The study of gravity wave excitation mechanism by using GOES/SMS infrared data has been attempted.

Current Focus of Research Work:

The necessary and sufficient conditions for the generation of gravity waves associated with severe storms are not well understood. The thorough understanding of the wave excitation mechanism can be contributed greatly to the early prediction of severe storms. The study of the GOES/SMS infrared (IR) data during the time period between the gravity waves were being excited, and the touchdown of the tornado, has currently been focused.

Based on the May 29, 1977 case study of the Oklahoma tornado, it was found that clouds associated with tornado activity are characterized by both a very low temperature at the cloud top, and a very high growth rate of the cold region of the cloud top, the signature of enhanced convections in the cloud. Comparison between the gravity wave observations and the GOES IR digital analysis shows that gravity waves were excited when the cold region of the cloud-top was growing rapidly. From the data available for this analysis, we observe more than one hour leadtime before the touchdown of the tornado. It is also shown in the analysis that the lower temperature region of the cloud element collapsed before the touchdown of the tornado. This result is in good agreement with the aircraft observations of overshooting tops discussed by Fujita

(1973), Shenk (1974), Black (1977), etc.

Plans for **FY-80**:

Continuation of the research on investigating the characteristics of gravity waves associated with tornadoes, the study of wave generation mechanism, and the conditions for tornado initiation are planned.

To give a more specific example, seven gravity waves associated with three isolated tornadoes on January 13, 1976 were detected. There were two squall lines, one at the north and the other at the south of the mideastern United States. Ray tracing of the observed gravity waves indicate that all were excited along the northern squall line. Three isolated tornadoes were reported along the northern squall line while none were reported along the southern squall line. The radar summary showed that the echo height at the southern squall line was higher than the northern squall line. It is quite interesting to study the wave excitation mechanism by investigating the differences in the growth rate of the cloud heights and the time rate of change of temperature distribution associated with convective clouds in these two squall lines from GOES/SMS IR data.

Understanding of the wave triggering mechanisms can be significant for developing an early warning system of tornadoes.

Recommendations for New Research:

It has been shown that gravity waves were excited by enhanced convection more than one hour before the touchdown of the tornadoes. The necessary and sufficient conditions for the generation of gravity waves, the wave triggering mechanism, the conditions for initiation of tornadoes are all not fully understood so far. The combination of study of gravity waves from the Doppler sounder array and the study of the growth rate of convective clouds and time rate of change of temperature distribution of cloud top based on IR digital data from GOES/SMS photographs can be significant for the study of the evolution of severe storms.

TITLE: AIRBORNE DOPPLER LIDAR - SEVERE STORMS SYSTEMS

INVESTIGATORS: J. W. Bilbro  
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SIGNIFICANT ACCOMPLISHMENTS FY-79:

All major contracts have been awarded for hardware and software development for the test flight. Fabrication of the new signal processor was undertaken as well as the preliminary design of the central control unit which will interface all system components. In addition, system simulation was initiated for the purpose of evaluating various algorithms for flow field visualization.

A series of tests were completed under OAST funding using the lidar for Clear Air Turbulence (CAT) detection. These data will provide valuable information for the upcoming severe storms tests.

CURRENT FOCUS OF RESEARCH WORK:

Hardware modification for system improvements will continue along with software definition and algorithm development. Analysis of the CAT data as it applies to the severe storms program is underway.

PLANS FOR FY-80:

The signal processor, scanner, and central controller will be completed and integrated into the system. The transmitter section of the lidar will be overhauled along with much of the system electronics. A new telescope system will also be delivered. Software for data collection, processing, and display will be completed,

### **RECOMMENDATIONS FOR NEW RESEARCH:**

Following the severe storms test, this system could be utilized for a variety of atmospheric measurements such as determining the dispersion of the chemicals during cloud seeding operation.

OUTLINE OF ~~RESEARCH~~ ACTIVITY  
for  
NASA/MSFC FY-79 SEVERE ~~STORMS~~ AND LOCAL WEATHER RESEARCH ~~REVIEW~~

TITLE: AWE Sesame '79

RESEARCH  
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SIGNIFICANT  
ACCOMPLISHMENTS  
FY 79

NASA's Marshall Space Flight Center (MSFC) participated with its AVE (Atmospheric Variability Experiment) in a large interagency mesoscale and severe storms experiment identified herein as AVE-SESAME '79 (Atmospheric Variability Experiment - Severe Environmental Storms and Mesoscale Experiment 1979), (Hill, et. al., 1979). A primary objective of NASA was to support an effort to acquire carefully edited sets of rawinsonde data during selected severe weather events for use in correlative and diagnostic studies with satellite and radar data obtained at approximately the same time. Data were acquired during six individual 24-hour experiments on both the regional and storm scales over a network in the Central U. S. which utilized approximately 20 supplemental rawinsonde sites meshed among 23 standard National Weather Service Sites. Included among the six experiments are data obtained between 1200 GMT 10 April and 1200 GMT 11 April, encompassing the formation and development period for the tornado producing systems that devastated Wichita Falls, Texas, and other sections of Oklahoma and Texas. The other dates for which data sets are available are April 19-20, 25-26, May 9-10, 20-21, and June 7-8, 1979.

Reference: "NASA's Participation in the AVE-SESAME '79 Program", Kelly Hill, G. Wilson and R. Turner, Bulletin American Meteorological Society, to be Published November 1979

CURRENT FOCUS OF  
RESEARCH WORK

The major focus for the coming months will continue to be the processing reduction of the rawinsonde data from the **six** experiment periods contained within the AVE-SESAME '79 field study. Tapes and hard copies for each of the cases will be available in late 1979 upon request to Director, Space Sciences Laboratory, MSFC, Alabama 35812. Data from all previous AVE's will be available with a listing of reference publications which document the results from various research efforts which have utilized these data to date.

PLANS FOR FY80

The AVE-SESAME '79 rawinsonde data reduction work will be completed.

If funding **is** available, a small AVE type experiment will be planned and conducted which will provide the continuity in our field experiment work necessary for conducting an extensive field program associated with the **VAS** Demonstration in 1981.

Title: Relationships Between Severe Storms and Their Environment

Principal Investigator: Dr. James R. Scoggins  
Department of Meteorology  
Texas A&M University  
College Station, Texas 77843  
Phone No.: 713-845-7671

Significant Accomplishments FY-79: A study of three-dimensional trajectories of air particles traversing convective **storm** regions was completed. A report by Dr. Gregory S. Wilson is **now in** publication which presents the results. The study considers convective instability, vertical motion, the energy source of convective storms, and energy processes following parcels traversing severe storm areas. The results demonstrate the high degree of interaction between synoptic and mesoscale systems,

A study of satellite capabilities was concluded and a report completed. This study considers **RMS** errors in the basic variables including temperature, geopotential height, wind speed, and mixing ratio as well as errors in derived parameters including gradients of the basic variables, advection of temperature, relative vorticity, and lapse rate of temperature. **It is shown** that in all cases errors in satellite parameters **are** larger than errors in the corresponding parameters determined from rawinsonde data. Results are compared with mean arid near extreme values of parameters determined from rawinsonde data, and **it is shown** that in regions of near extreme values satellite data **may** be used quite effectively to determine patterns of the meteorological variables on constant pressure surfaces.

A report titled, "Differences Between Measured and Linearly Interpolated Synoptic Variables Over a 12-h Period During AVE IV," by Dupuis and Scoggins was completed and printed as NASA CR-3150. Included in this study were **both** basic and derived variables. A statistical analysis of the differences between interpolated and measured values was performed and the vertical structure investigated both temporally and spatially. **It was shown** that systems with a time scale less than 12 h exhibited both time and space continuity and were related to synoptic features. In some cases, these systems which would be missed entirely by an analysis of 12-h rawinsonde data are responsible for much of the observed significant weather.

**An** MS thesis was completed by Mr. James G. Davis titled, "The Development of Convective Instability in Relation to Convective Activity and Synoptic Systems in AVE IV." Also, similar studies for wind shear and vertical motion were completed and are being integrated along with Mr. Davis' thesis into a single report. This study was approached by developing equations which show the processes responsible for local changes in the chosen parameters, and evaluating the magnitudes of the various terms in the equations to determine the relative importance of each process to a local change. The parameters of convective instability, vertical motion, and wind sheer were chosen because of their relationships to convective activity.

Rawinsonde soundings were processed for the AVE VII experiment and a data report prepared. In addition, soundings were processed for the first AVE-SESAME day and the processing is underway for the second day. The rawinsonde data for these experiments are thoroughly checked to insure accurate data for scientific investigations.

Current Focus of Research Work: Our current emphasis is on the conclusion of the tasks described above and primarily on documentation of the research. Also, emphasis is being placed on the processing of the first two days of the AVE-SESAME sounding data,

Plans for FY-80: Assuming that funding is available, we plan to process the remainder of the AVE-SESAME data, resume diagnostic analyses of the environment of severe storms using AVE, AVE-SESAME, and satellite data, and participate in the evaluation of the VAS system,

Recommendations for New Research:

1. Prepare an indepth assessment of satellite measurement capabilities, and of the utility and interpretation of quantitative satellite data.
2. Stress improvement (if needed), utilization, and interpretation of satellite sounding data, particularly on meso and storm scales,
3. Emphasize diagnostic studies of mesoscale energy processes, storm formation, and storm-environment interactions.
4. Development of mathematical models to explain observed phenomena and for forecasting with emphasis on time periods less than 12 hours,

OUTLINE OF RESEARCH ACTIVITY  
for  
NASA/MSFC FY-79 SEVERE STORMS AND LOCAL WEATHER RESEARCH REVIEW

TITLE: Mesoscale Structure and Dynamics in Relation to Severe Storm Development

RESEARCH INVESTIGATOR: Gregory S. Wilson, ES84  
Atmospheric Sciences Division  
Space Sciences Laboratory  
Marshall Space Flight Center  
Huntsville, Alabama 35812  
205-453-2570 or FTS 872-2570

SIGNIFICANT ACCOMPLISHMENTS FY-79:

I. Determination of Mesoscale Spectral Characteristics of wind components, temperatures, and moisture, using structure functions derived from the entire AVE data base (8 experiments).

11. Development of a Monthly and Seasonal Severe Storms Climatology for the U. S. east of the Rockies, using Manually Digitized Radar (MDR) data.

A. Relative frequency of occurrence of precipitation, thunderstorms, severe thunderstorms, and flash floods.

B. Total time-integrated precipitation from MDR-rainfall rate relationships.

III. Diagnostic analysis of the mesoscale aspects of **thunderstorm-environment** interactions. Involved is a study of mesoscale conditions prior to severe storm development (pre-storm effects) and the effects of the storms on their environment (feedback effects).

A. Subsynoptic Analysis

1. Determination of the dynamical aspects involved in the interaction between lines of severe thunderstorms and their environment. These results, determined from AVE and satellite data utilizing three-dimensional trajectory calculations and budgets of moisture, sensible heat, and kinetic energy, have been reported in the 11th AMS Severe Storms Conference, in the paper "Interactions Between Lines of Severe Thunderstorms and Their Synoptic-Scale Environment."

2. Completion of NASA contract report entitled, "Thunderstorm-Environment Interactions Determined with Three-Dimensional Trajectories."

B. Regional (meso- $\alpha$ ) analysis

1. Development of a computer-based analysis system for determining meso- $\alpha$  atmospheric structure and dynamics from surface, rawinsonde (AVE), and satellite data.

2. Development of a three-dimensional trajectory package applicable to 1. above.

3. Determination of both pre-storm and feedback aspects of severe storm formation utilizing 1. and 2. above.

C. Meso- $\beta$  analysis (Texas HIPLEX Data)

1. Computation of the kinematics and dynamics of the meso- $\beta$  environment of thunderstorms using heat, moisture, and kinetic energy budgets.

2. Relate results of 1. to conditions at the surface.

IV. Development of a Medium Range (6-48 h) Thunderstorm and Severe Weather Forecasting System. Case study results of the system have been reported in the 11th AMS Conference on Severe Local Storms in the paper "Medium Range Forecasting of Thunderstorm Location and Severity Using Regional-Scale Atmospheric Structure and Dynamics Predicted by the LFM2 Model."

#### CURRENT FOCUS OF RESEARCH WORK:

I. Interpret mesoscale spectral characteristics in terms of unresolved variance of basic variables in various space-time domains.

II. Physical interpretation of radar (MDR)-derived Severe Storm Climatology.

111. Analysis of NASA's AVE IV experiment data with emphasis on the regional-scale results from (111. 2b) above including quantitative calculations from SMS imagery (limited scan data).

IV. Acquisition of a predictor (LFMZ forecast)-predictand (MDR radar data) data base to develop improvements to the medium-range severe weather forecast system.

#### PLANS FOR FY80:

I. Expand space-time domain of mesoscale spectral characteristics by analyzing AVE-SESAME Experiments (6).

11. Improve radar (MDR) - derived severe storm climatology using a larger data base (1973-1979) and improved analysis techniques.

III. Integrate diagnostic results from the synoptic, meso- $\alpha$ , and meso- $\beta$  analyses to produce a descriptive-dynamical model for both pre-storm and feedback thunderstorm-environment interactions. This task requires the use of AVE and AVE-SESAME rawinsonde and satellite data including satellite-derived winds and precipitation rates with mesoscale accuracy (proposal submitted to NASA for the satellite work).

IV. Develop a statistical-dynamical medium-range severe storm forecast system (including thunderstorms, severe thunderstorms, and flash floods) using a predictor-predictand data base of LFM2 forecasts and radar (MDR) data and incorporating the severe storm climatology in the procedure.

#### RECOMMENDATIONS FOR NEW RESEARCH:

I. Implementation of an operational medium-range severe storm forecast system (as currently exists) supplemented by real-time satellite data processed on an interactive computer system.

II. Comparisons between the diagnostically determined and numerically simulated atmospheric state during severe weather events.

111. Modifications to numerical models, based upon diagnostically determined thunderstorm-environment interactions, to include better sub-grid scale parameterization and initial conditions as supplemented by satellite temperature, moisture, wind and precipitation rate measurements.

## Studies of Frontogenesis Using AVE Data

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During 1979 our main aim has been the development of a numerical interpolation scheme suitable for the analysis of atmospheric baroclinity and the terms which result in changes of baroclinity over time. We have put considerable effort into the extension of the Barnes (1973) two dimensional technique to a fully three dimensional scheme. The resulting method, using separate and unequal weights for vertical and horizontal distances has the advantages of producing analyses in which unresolvable features may be filtered out while considerable detail is still retained. The vertical filtering is especially important in the analysis of the wind field; short vertical wavelength features which normally contaminate horizontal analyses are effectively eliminated. Among the chief disadvantages of the method are its considerable demands on computer storage and time. We presently use a one degree latitude by one degree longitude horizontal grid with a twenty five millibar vertical interval. This includes some 22,113 grid points to cover the AVE II area from the ground to 100 mb.

The output of the program includes grid point values of potential temperature, u and v wind components, and mixing ratio at all grid points. From this basic output we construct constant pressure maps at 25 mb intervals as well as cross sections along any latitude or longitude line within the analysis domain. Additional derived quantities such as baroclinity and vertical velocity are also available in the same form.

Our current focus is upon obtaining a clear three dimensional picture of the baroclinity and its temporal variation. We are also experimenting with the computation of terms in an Eulerian frontogenesis equation toward the goal of improving our understanding of the motion and development of fronts,

Our contract with NASA officially terminated in June but we hope to prepare a proposal for continued work along three major avenues.

First, we wish to make improvements in the analysis scheme by more complete testing of the vertical and horizontal weights. This requires numerical experimentation coupled with meteorological judgement concerning the validity of the analyzed fields. We also wish to perform experiments with a complete three dimensional scheme using potential temperature as the vertical coordinate; this should result in significant improvements in the horizontal resolution of frontal phenomena if it proves practical. Further, we believe the method holds promise for the assimilation of satellite sounding data into a consistent three dimensional analysis.

Second, we have begun examination of fields of stability index derived from the analyzed fields and want to apply the method to the analysis of severe

weather cases. Here, we want to look into the processes which cause the reduction of static stability preceding severe thunderstorm formation.

Third, we would like to continue studies of the frontogenesis processes not only for their intrinsic interest, but also because some of these processes, for example the vertical motions, are intimately tied to the development of severe weather which sometimes accompanies fronts.

# Kinetic Energy Budgets in Areas of Intense Convection

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## I. Goal of the Research

Our purpose is to study the kinetic energy balance of the environments of severe **storm** areas. AVE and SESAME rawinsonde data at 3 h intervals are used as input data to the energy equations while radar and satellite data are used to monitor the development and movement of the convection being studied. Through this study we **hope** to better understand **how** severe thunderstorms **form** and interact with their surroundings.

## II. Accomplishments During FY-1979

- A. Energy **studies** were performed **for** the periods of AVE 7 (May 1978), AVSSE 1 (April 1975), and AVSSE 2 (May 1975) **when** severe **storms** occurred. Studies of AVE 3 (February 1975) and AVE 4 (April 1975) have been conducted prior to FY-79.
- B. Generation and transport of kinetic energy in the storm environments often were found to be greatest when the convection was near peak intensity.
- C. The storm environments often were characterized by **generation** of kinetic energy by cross-contour flow (the major source) and dissipation of energy to subgrid scales (**the** major sink). Synoptic-scale upward transport of energy and upper-level flux divergence of energy were common.
- D. Every storm environment was not characterized by the conditions described in C above.

## III. Current Focus of Research

- A. Several additional case studies are underway. These involve AVE 6 (May 1978) and AVE-SESAME I (April 1979).
- B. During these **studies**, we will investigate:
  - 1. Relationships between spatial fields of kinetic energy budget terms and the locations and movements of severe storms.
  - 2. Synoptic-scale energy budgets of individual storm areas.

3. Relationships between temporal variations in the energy budget terms and the life cycles of the convection.
4. Relationships between kinetic energy variability and storm intensity.

#### IV. Plans For FY-1980

AVE rawinsonde data were taken at 3 h intervals but are still synoptic-scale due to a station spacing of about 400 km. The 1979 series of AVE-SESAME rawinsonde data, taken with a station spacing of 200 km and 100 km, provide the opportunity to study severe storm formation and storm-environment interactions at scales that previously were not possible. Additional kinetic energy studies using these unique data sets should be performed. Our plan is to first study the synoptic scale kinetic energy balance in isolation by using only the standard NWS rawinsonde data and then to study the subsynoptic scale budget by adding the special rawinsonde data that had initially been withheld. Satellite and radar data will be used extensively to study the variability of the severe storms.

#### V. Recommendations for New Research

- A. The study of subsynoptic scale energy budgets using AVE-SESAME data will extend beyond FY-1980. The work should be continued so that cases having the best convection (about 4 of the 6 periods) are investigated.
- B. VAS will provide mesoscale sounding data which were previously not available. These thermal data should be evaluated for "around truth" by comparing with AVE data to be collected and then used to compute winds. Special attention would be placed on low-level winds since they have been found to be important to severe storm development. Accuracy of the derived winds should be evaluated, and the ability to compute simple kinematic parameters such as divergence and vorticity from the satellite-derived winds should be investigated. Certain energy parameters also could be computed from the derived winds depending on their accuracy.
- C. Numerical storm modelling, using AVE-SESAME data as environmental boundary conditions, should be undertaken to study storm-environment interactions on a fine scale. Sensitivity studies of the various input parameters would be performed to help explain why severe storms occur on some occasions and not on others and to help us exploit the finer scale satellite data that is becoming available. Results of the modelling study would help explain the observed energy variability in the various AVE-SESAME cases.

Title: Diagnostics of Severe Convection and Subsynchronous Scale Ageostrophic Circulations

Research Investigator: Donald R. Johnson  
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Significant Accomplishments FY-79: (For the period 6/1/79 - 8/31/79)

The primary thrust during the initial three months of the research supported by NASA NAS8-33222 has been the organization of several efforts in analysis of severe convection and numerical simulation of the mesoscale circulations. Diagnostic analyses using AVE IV observations of severe weather that developed in the Midwest have been initiated. The rawinsonde data has been interpolated to grid points on a  $1^\circ$  by  $1^\circ$  mesh using the Barnes method and then interpolated from isobaric to isentropic coordinates. A comparison of the height and temperature fields from the interpolation to isentropic coordinates with the basic information on isobaric surfaces is being made. Some problems have been encountered in retaining consistent temporal and spatial scales during the interpolation to isentropic coordinates.

Two preliminary accomplishments in the numerical modeling area are: the initialization of momentum from the assumed mass distribution using a steady state model for propagating jets has been successfully calculated for one case; the second effort involves the design and testing of a finite difference method for insuring momentum conservation during calculations of the pressure gradient force. The method is a combination of a scheme proposed by Phillips to minimize truncation errors in regions of variable terrain and the determination of the pressure gradient force from surface pressure stresses. In a comparative study with four other methods to calculate the pressure gradient force, our modification of Phillips' scheme suppresses spurious excitation of noise and yields the best results for jets propagating over mountainous terrain. This later work results from cooperative efforts with Dr. Louis Uccellini of Goddard.

Current Focus of Research Work:

The focus of the research work is to study the forcing of severe storms by the combination of larger scale mass-momentum adjustment, release of latent heat and boundary processes through use of the AVE data set and numerical simulations. Through numerical simulation the relative importance of the components of ageostrophic motion associated with inertial, isallobaric, diabatic and viscous processes will be ascertained.

Plans for FY-80:

The efforts during FY-80 will be to continue with the work initiated during the past three months. The case study of the severe weather using the higher temporal and spatial resolution of the AVE IV rawinsonde data will be

continued in order to study the relative role of inertial, isallobaric and diabatic processes in the forcing of ageostrophic motion. The validity of estimates of latent heat determined from the isentropic equation of continuity will be checked against parameterization of the release of latent heat determined from the observed precipitation distribution during this period. The focus of the research in numerical studies will be to incorporate degrees of freedom for moist adiabatic and viscous processes in the Uccellini, Johnson and Schlesinger hybrid model. Early variations of this model used to study **mass** momentum adjustment were developed for adiabatic inviscid motion. Comparative numerical simulations will be designed to study the relative importance of terrain, friction and release of latent heat in the development of severe weather through an assessment of the ageostrophic circulations realized in numerical simulations.

#### Recommendations for New Research:

As the data for the SESAME period becomes available, comparative diagnostic and numerical studies of **mass** momentum adjustment are recommended for this data set. The goal is to ascertain 1/ the processes important for the development of deep convection, and 2/ the modes through which the **mass** circulations attending deep convection become linked to larger scale circulations.

Title: Spectral Characteristics of Mesoscale Variables

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Significant Accomplishments FY-79: The behavior of Eulerian frequency spectra of mesoscale variables (zonal (u) and meridional (v) wind components, potential temperature ( $\theta$ ), and mixing ratio (m)) for radian frequencies in the interval  $0.25 < \omega < 1 \text{ rad hr}^{-1}$  have been determined for the AVE 1 through 7 and AVSSE 1, 2 data sets. Time domain structure functions were determined for each variable for each data set for selected pressure levels ranging between 975 and 400 mb. The structure functions were recalculated for time lag  $\tau$  ranging from 3 to 24 hr. These functions were characterized by power law behavior,  $\tau^{q-1}$ , where  $q > 1$  and depends on pressure level. Through the use of a well known Fourier transform theorem it is shown that the corresponding spectral density functions also have power law behavior given by  $\omega^{-q}$ . The values of  $q_u$ ,  $q_v$ , and  $q_\theta$  typically range between 1.6 and 2.1 with somewhat similar variation with altitude, i.e., maximum value in the neighborhood of 975 mb and tending to take on constant value above the 800 mb level. The quantity  $q_m$  ranges between 1.3 and 2.1 and also takes on maximum value near the ground, in the neighborhood of the 950 mb level, but decreases dramatically with height above this level. The mesoscale spectral behavior for the zonal and meridional winds have values of  $q$  approximately equal to those of corresponding synoptic scale Eulerian frequency spectra published by Kao et. al. (JAS, 27, 1970).

Current Focus: To obtain and explain spectral characteristics of mesoscale field variables. The research is aimed at quantifying atmospheric variability in terms of length and time scales for application to mesoscale field program planning.

Plans for FY-80: We plan to update these research results by including the recent AVESESAME data sets. If feasible

the analysis will be expanded to include the estimation of wave number spectra. Finally, the unresolved variance of mesoscale variables will be calculated as a function of sampling time and space interval for planning mesoscale field experiments.

Recommendations for New Research: Development of spectral equations for mesoscale fields should be pursued. This would provide a basis for examining the dispersive properties of mesoscale fields, and provide insight relative to explaining the measured spectra.

RESEARCH ACTIVITY: ANALYSIS OF MACROTURBULENCE STRUCTURE AND CORRELATION FUNCTIONS

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INTRODUCTION:

The theory of local isotropic turbulence has been completely substantiated in the case of atmospheric turbulence. Its area of application increases with distance from the earth's surface, since the integral length scale typically increases with height  $z$ . A question arises as to whether a statistical relationship exists between the values of meteorological elements at two significantly distant points separated by a distance  $r$  or for two sufficiently large intervals of time,  $\tau$ ; and, if it exists, how can it be analytically expressed.

This question has great theoretical and practical significance. Data about statistical macrostructure of meteorological elements have a wide range of applications, i.e., estimating a net of meteorological stations and intervals of observation; ordering derivatives of meteorological elements for simplification of equations of atmospheric dynamics in meteorological investigations; error of interpolation in space and time of values of meteorological elements relative to construction of a net of points for a numerical analysis and weather prediction; filtering of unnecessary perturbations to increase the stability of approximate solutions for equations of atmospheric motion; etc. All of these applications indicate the significance of research related to statistical relationships which exist between large-scale values of meteorological elements. Although the characteristic fields of meteorological elements concerned with large synoptic scale motion of the atmosphere prove to be strongly anisotropic in a vertical direction there are grounds for regarding large-scale atmospheric motion as turbulence for motions in a horizontal plane. Since horizontal scales of atmospheric motion are actually finite, it is convenient to consider the random fluctuations,  $f'$ , of a given meteorological element, say  $f$ , from the climatic norm,  $\bar{f}$ , as homogeneous and isotropic in the horizontal plane, i.e.,  $\bar{f} = \text{constant}$ . Based on this assumption one can derive the functions

Correlation Function

$$B_{ff}(r) = \overline{f'(x+r)f'(x)} \quad ; \quad \sigma f^2 = \overline{f'^2} = \text{constant}$$

Structure Function

$$D_{ff}(r) = \overline{[f'(x+r) - f'(x)]^2}$$

The AVE data constitutes one of the most unique sets of data for empirically and analytically investigation of the characteristics of these functions.

RESEARCH CONDUCTED TO DATE:

The structure function for the  $u$  and  $v$  velocity components for the AVE II, AVE III, AVE IV, AVSSE I, and AVSSE II data have been computed. A computer

program for this computation has been developed. Values of the structure function for 14 pressure levels from 1000 to 300-MB are available for time intervals,  $\tau$ , of 3, 6, 9, 12, 15, 18, 21, and 24 hours. Plots of the resulting structure function versus  $\tau$  have been made and empirical values of the slope of the correlation have been computed.

#### CURRENT FOCUS OF RESEARCH WORK:

Computation of the spacial structure function for all AVE data and of the temporal structure function for the new AVE/SESAME data. Analysis of the processed data to provide the information in a usable format.

#### RECOMMENDATIONS FOR NEW RESEARCH:

Both the spacial and temporal structure function and correlation function will be computed for all existing data. The assumption of homogeneity and isotropy for the functions will be tested as follows.

If  $\bar{f} \neq \text{const}$ , the assumption of homogeneity and isotropy is not satisfied for the element  $f$ , i.e.,

$$B_{ff}(r) = B_{ff}(x, r) - \bar{f}(x)\bar{f}(x + r) \quad (1)$$

$$D_{ff}(r) = D_{ff}(x, r) - [\bar{f}(x + r) - \bar{f}(x)]^2 \quad (2)$$

The condition of statistical homogeneity should be satisfied to an even greater degree with respect to the normalized field  $\phi = f'/\sigma_f$  since everywhere  $\sigma_\phi^2 = 1$ . This will also be tested.

The initial values of the investigated meteorological elements contain a certain error of observation,  $\delta_f$ , that is  $\tilde{f} = f + \delta_f$  where  $f$  is the true value. If the errors are purely random, their mean value equals zero and they do not correlate with true values and with each other; then as can be shown,

$$\tilde{D}_{ff}(r) = D_{ff}(r) + 2\overline{\delta_f^2} \quad (3)$$

whence

$$\tilde{D}_{ff}(0) = 2\overline{\delta_f^2} \quad (4)$$

Here  $\tilde{D}_{ff}(r)$  is a structure function constructed according to the given observations of the element  $f$ ;  $D_{ff}(r)$  is a true structure function of the same element. Equation (4) permits an indirect evaluation of the mean square of the error of observation by means of the extrapolation of the curve  $\tilde{D}_{ff}(r)$  to zero. After  $2\overline{\delta_f^2}$  is found,

$$D_{ff}(r) = \tilde{D}_{ff}(r) - 2\overline{\delta_f^2} \quad (5)$$

is also determined with the parallel transfer of the empirical curve,  $\tilde{D}_{ff}(r)$ .

The structure function and correlation function will be corrected for errors of observation and an empirical investigation will be carried out.

Research on the variability of wind and temperature in the free atmosphere has shown that spacial and temporal structure functions of wind velocity and temperature in the free atmosphere are well approximated by power functions of the form:

$$D_{\ell\ell}(r) = a_u r^n ; D_{\ell\ell}(\tau) = b_u \tau^m \quad (6)$$

$$D_{TT}(r) = a_T r^p ; D_{TT}(\tau) = b_T \tau^q \quad (7)$$

The exponents in these equations prove to be close to unity, but further testing of this is necessary. A value of 2/3 for the exponents would occur if the theory of Kolmogorov-Obukhov is extended to the case of two-dimensional macroturbulence which is considered in this research. The spacial and time structure functions therefore become

$$\begin{aligned} D_{\ell\ell}(r) &= 3 \times 10^{-4}(\text{ms}^{-2})r ; D_{\ell\ell}(\tau) = 6 \times 10^{-4}(\text{m}^2\text{s}^{-3})\tau \\ D_{TT}(r) &= 2.5 \times 10^{-5}(\text{°C}^2\text{m}^{-1})r ; D_{TT}(\tau) = 2.1 \times 10^{-4}(\text{°C}^2\text{s}^{-1})\tau \end{aligned} \quad (8)$$

in the free atmosphere. The numerical values of the coefficients in Equation (8) are empirically determined. It has been established that these linear dependencies are true for  $r \approx 10^1$ - $10^3$  kilometers and  $\tau \approx 1$ -24 hours.

Application of the AVE data to verification of these preceding results will provide new insight and verification to existing information relative to structure functions in the atmosphere. Similar studies of the correlation function will be performed.

Other studies will be carried out with the data. The condition of isotropy of the random wind field will be tested. This test will be carried out by comparing the data with the following formula:

$$D_{cc}(r) = D_{\ell\ell}(r) + D_{nn}(r) = (r \frac{d}{dr} + 2)D_{\ell\ell}(r) \quad (9)$$

The same analyses as applied to wind velocity will be carried out for temperatures. If time permits macroturbulence spectra will be computed.

# ATTENDEES

## NASA/MSFC FY-79 SEVERE STORMS AND LOCAL WEATHER RESEARCH REVIEW

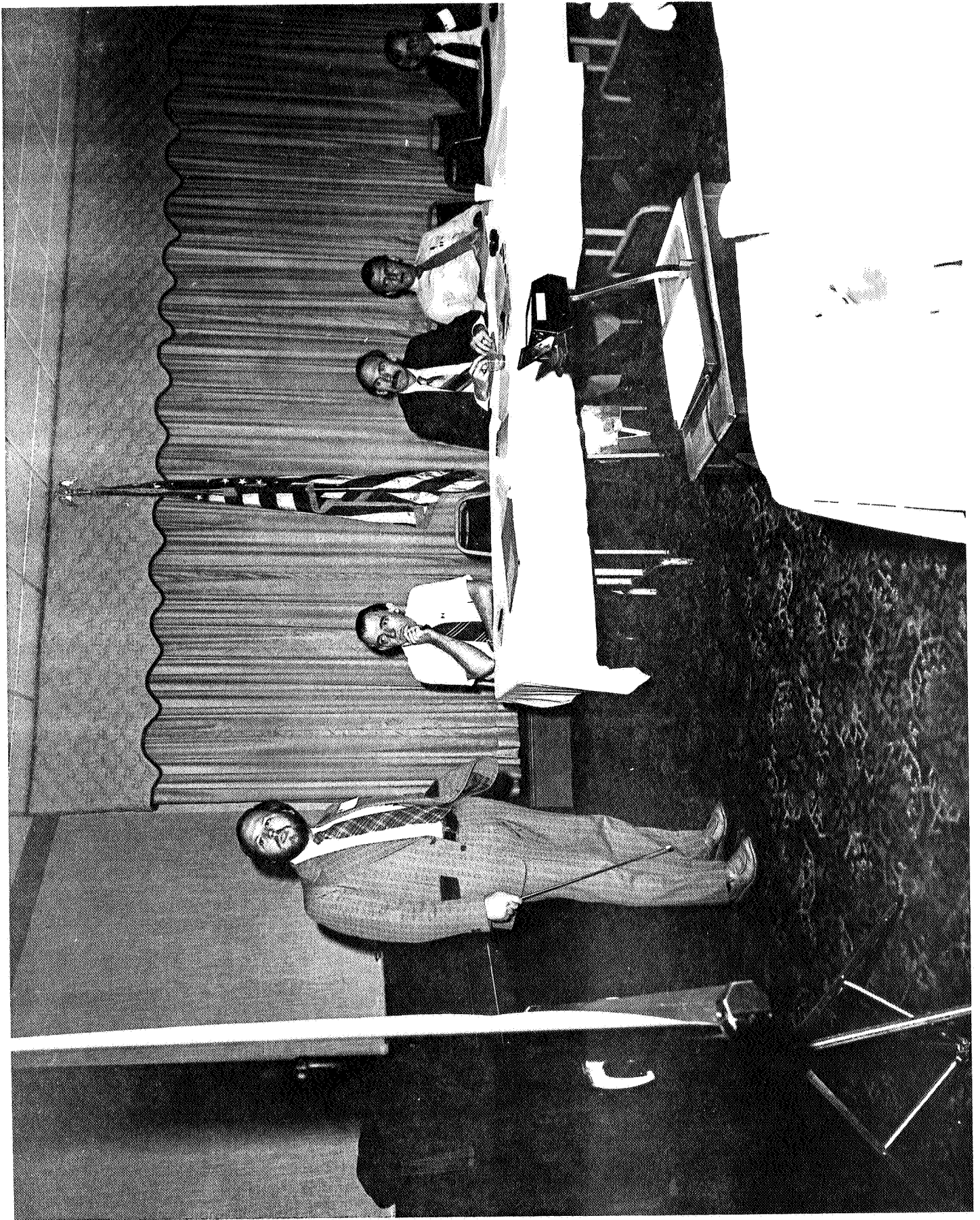
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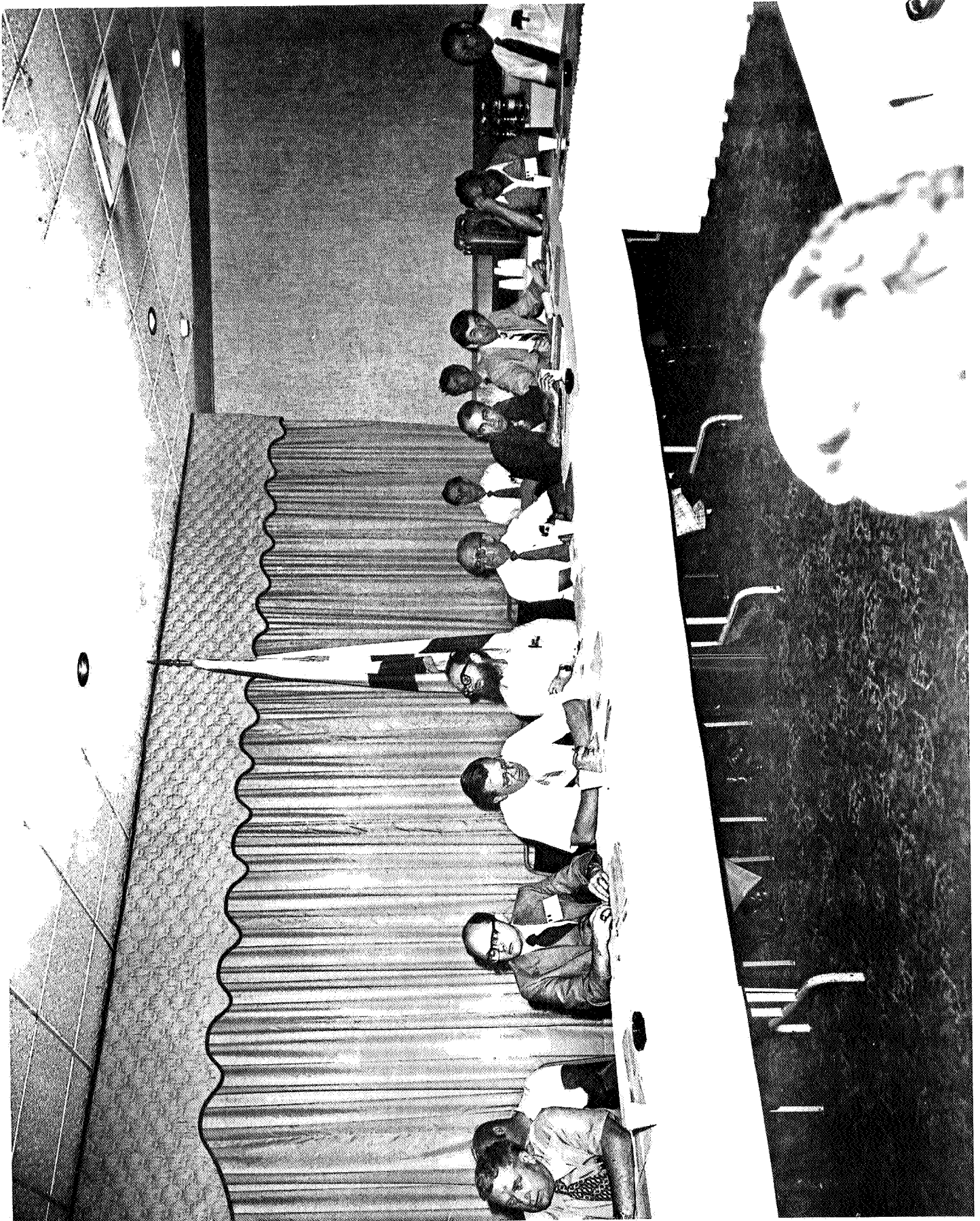
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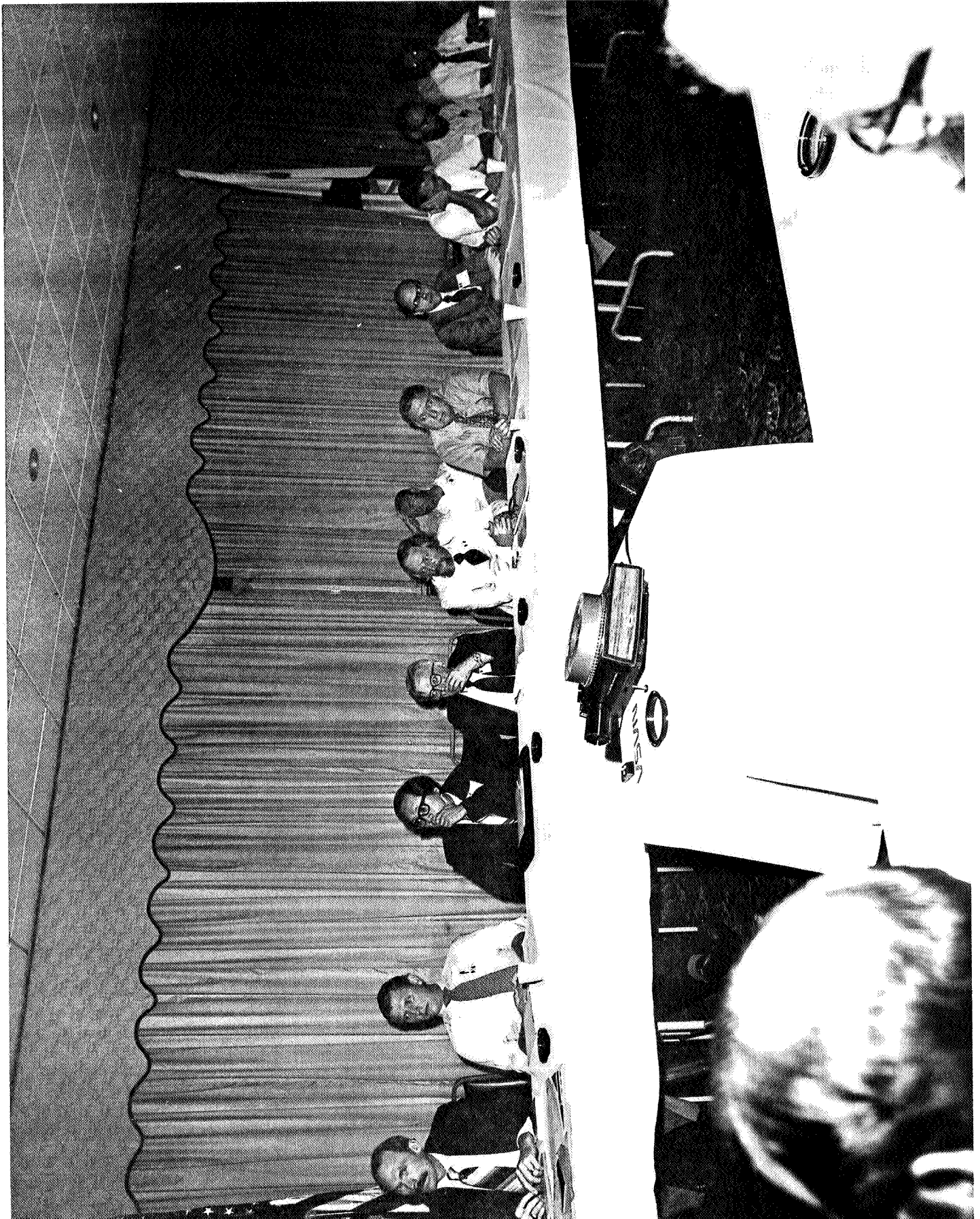
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## NASA/MSFC FY-79 SEVERE STORMS AND LOCAL WEATHER RESEARCH REVIEW

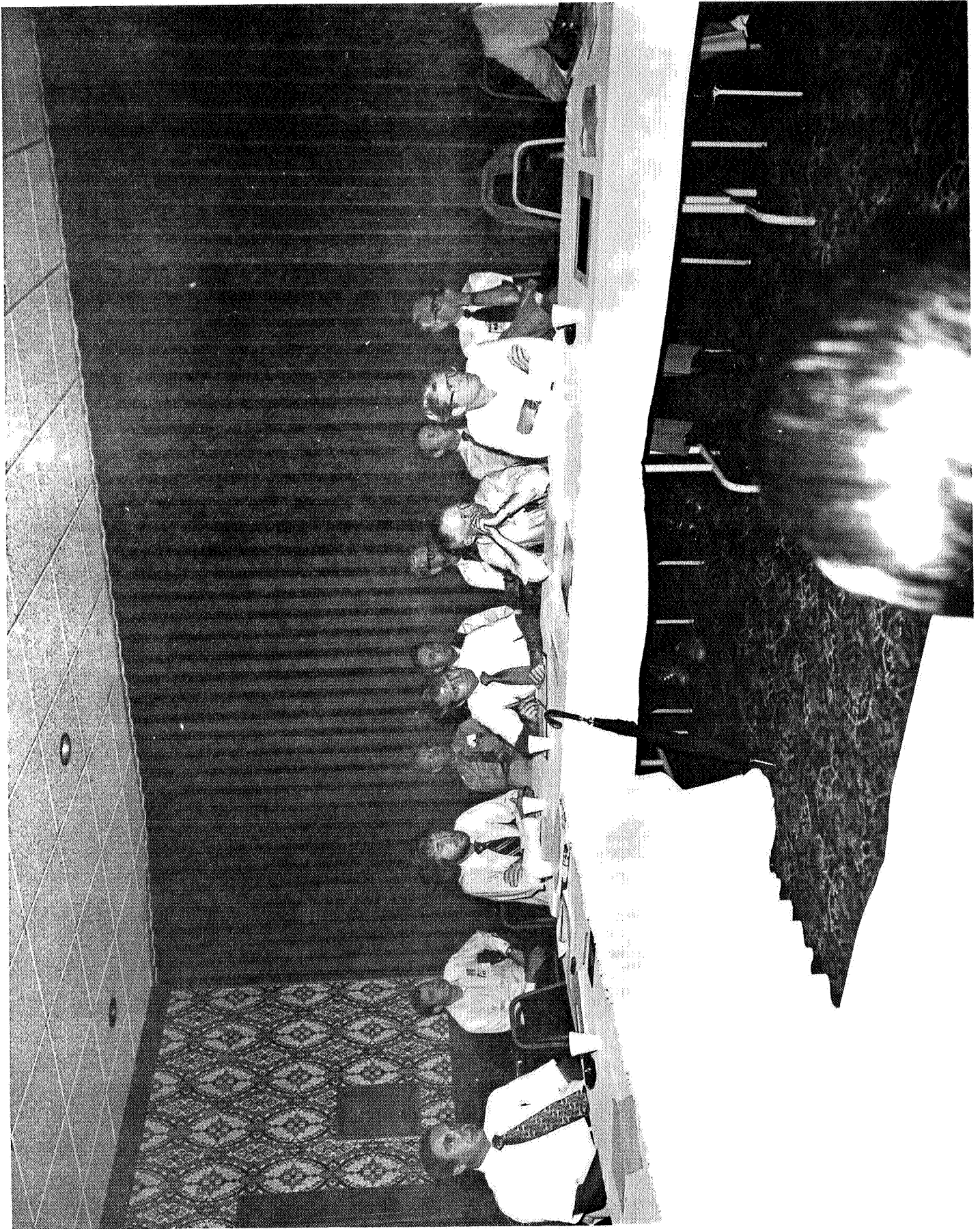
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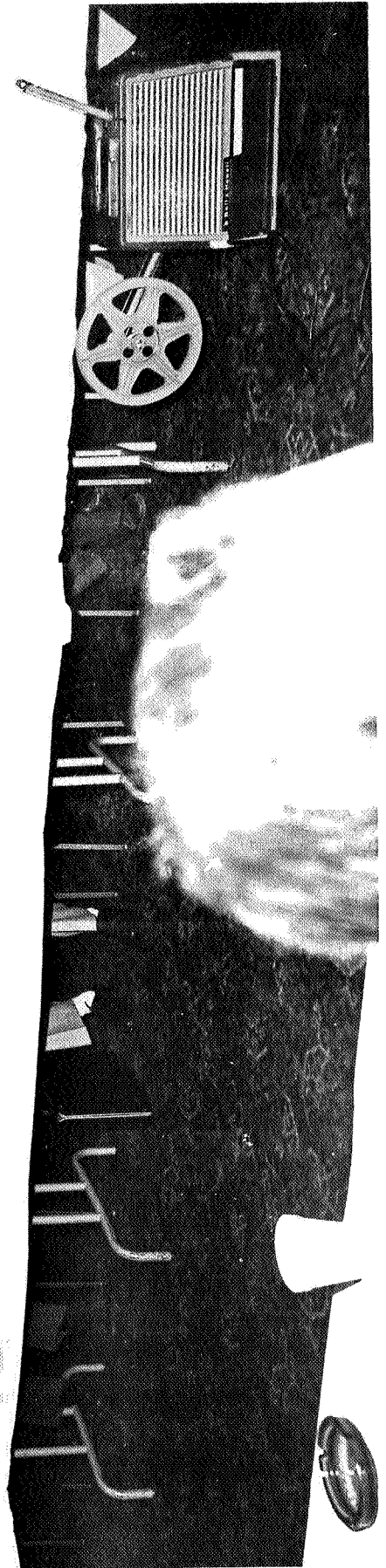
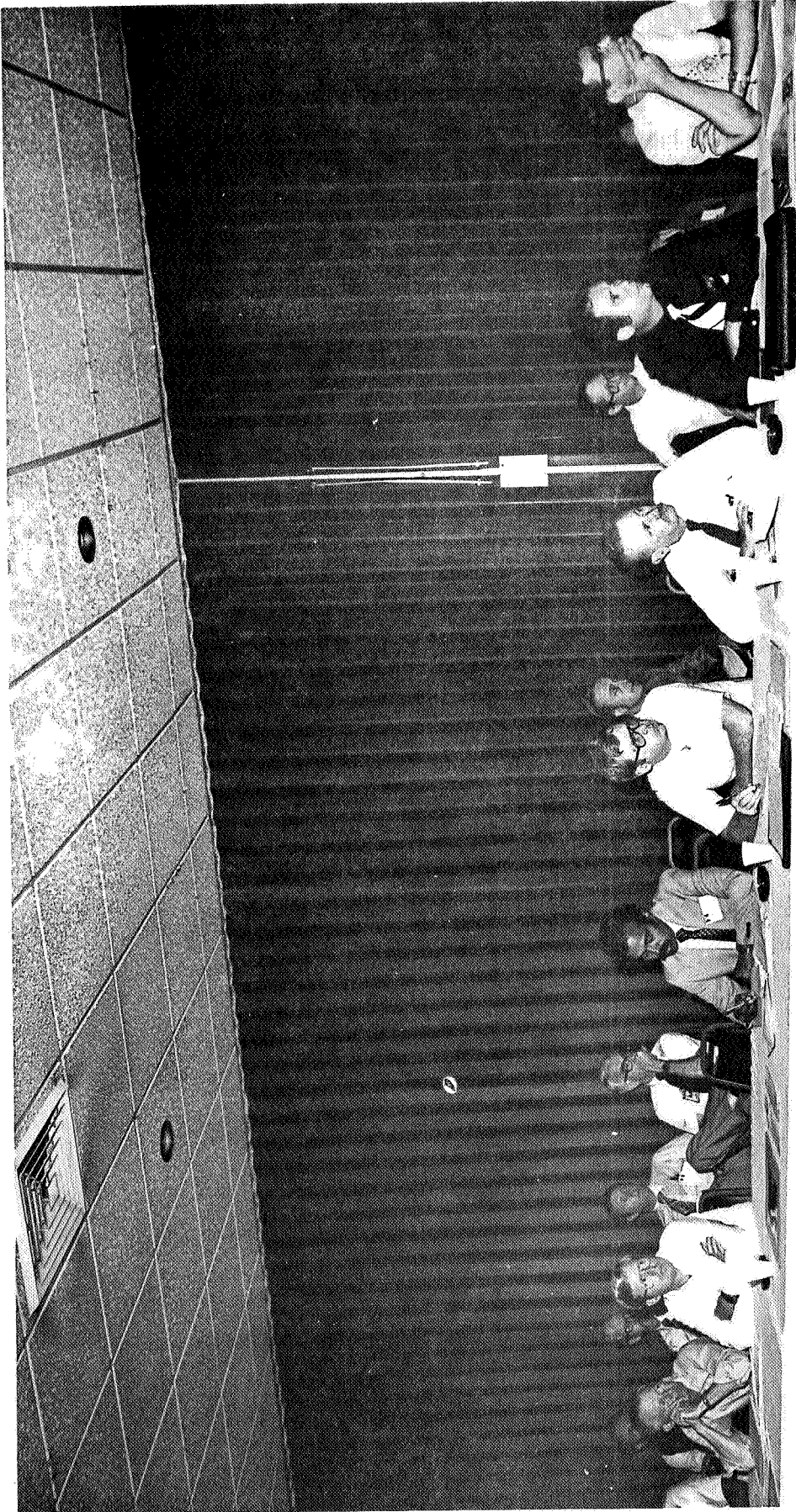


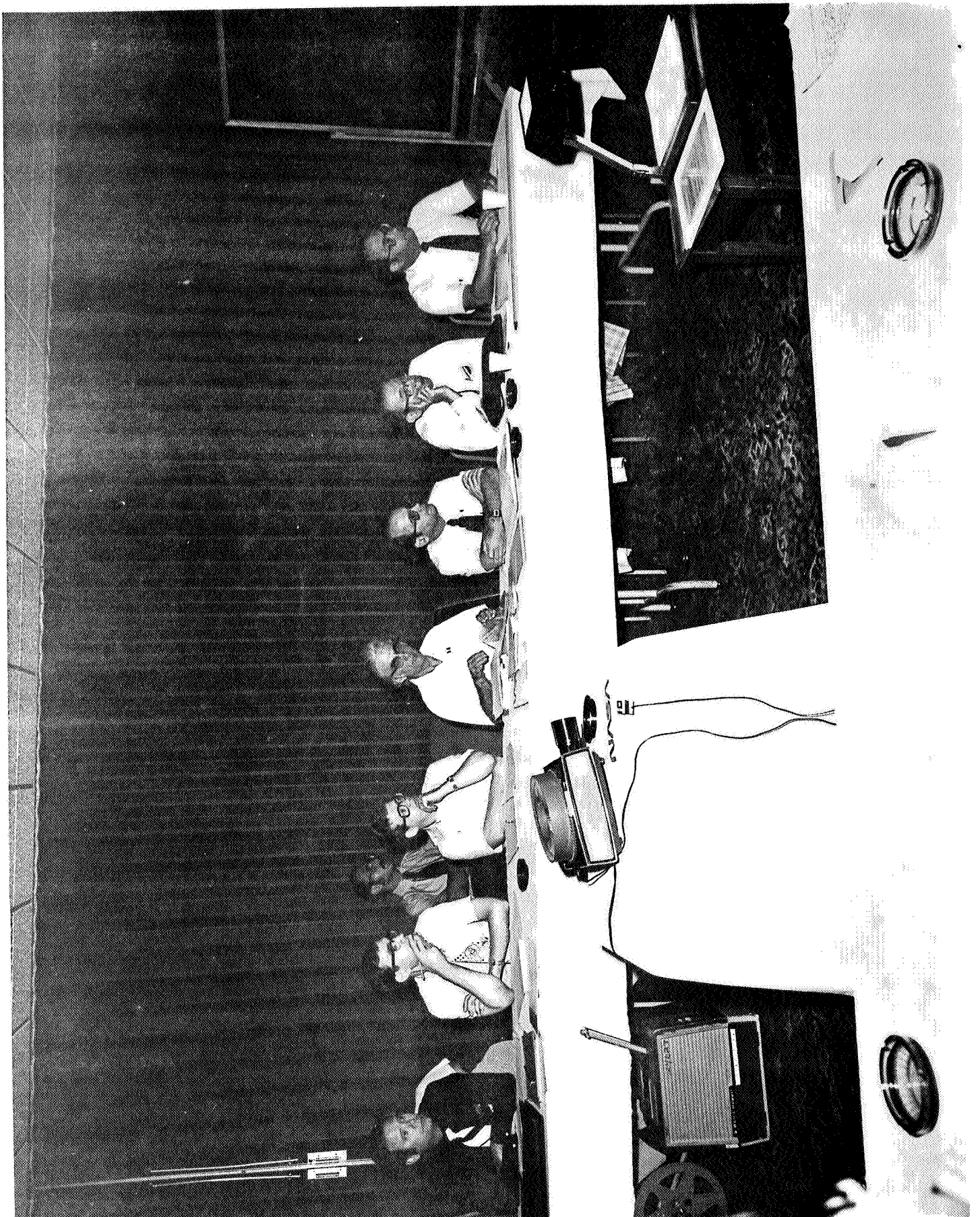








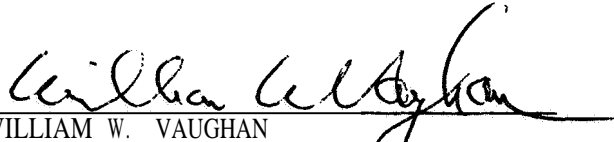





APPROVAL

SUMMARY OF THE NASA/MSFC FY-79 SEVERE STORMS  
AND LOCAL WEATHER RESEARCH REVIEW

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified,

  
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CHARLES A. LUNDQUIST  
Director, Space Sciences Laboratory